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OFFICIAL PUBLICATION OF THE AEROSPACE INDUSTRIES ASSOCIATION • WINTER 1984



- Arnold Engineering Development Center
- The Outlook For Space Commercialization



Notable views of notable people on aerospace matters...

aerospace perspectives

Leon Wieseltier, literary editor of *The New Republic* and author of *Nuclear War, Nuclear Peace*, writing in the *Los Angeles Times*:

"The nuclear debate of recent years has consisted of a contest between idealism and realism (deterrence) ... It is emotionally very difficult to make do with the idea that the greatest threat to human history should be met with concepts of management—which is what the idea of deterrence asks. And yet idealism is not the most responsible approach to the nuclear danger. Indeed, it is the very magnitude of the danger that makes idealism the least responsible method of anti-nuclear thought and anti-nuclear action ...

"I propose a division of intellectual and political labor. Let those who insist that there must be an idea that will end the nuclear era keep searching for the idea. They do not deserve to be scorned. But neither do those who insist that in the interim the danger must also be managed; and frequently they are.

"As Irving Howe has observed, there is the politics of the near and the politics of the far. Nuclear politics must allow for both. After all, when it is the destruction of the world that we are talking about, it is an honorable thing to trouble about the here and now. Somebody has to."

Robert MacFarlane, Assistant to the President for National Security Affairs, speaking to the Commonwealth Club in San Francisco, California:

"The result of U.S. weapons development during the '60s and '70s has been one of reducing unilaterally the size and number of our weapons. Did you know, for example, that the number of nuclear weapons in our arsenal today is 25 percent lower than 17 years ago and the megatonnage of those weapons is 75 percent lower than in the mid-1960s? Did you know that in 1979 we and our allies unilaterally removed 1,000 warheads from Europe? Did you know that last year President Reagan and our NATO allies agreed to the withdrawal of 1,400 more? These unilateral reductions were not the result of arms negotiation. The other side made no corresponding reductions. So Point Number One is that even without an arms control agreement your government has reduced arms ...

"Since the SALT I talks started in 1969, the Soviets have added over 7,000 nuclear weapons to their arsenal; since SALT II was signed, over 3,800 ... Point Number Two, therefore, is that arms control agreements do not necessarily reduce the level of arms ... Since the signing of the SALT I agreements in 1972, we have built only two strategic systems while the Soviets have built 31. Point Number Three is that agreements have not induced a Soviet attitude of restraint. Point Number Four concerns compliance. Soviet violations of agreements ... undercut any argument that agreements

with the Soviets are grounds for greater confidence in our safety.

"What should we conclude from this history—that arms control is hopeless? Surely not. There have been times when we have succeeded. They have come when the Soviets have had to accept that, unless they come to terms, we are prepared to build a better system than they."

Verne Orr, Secretary of the Air Force, in an address to the Air Force Association National Convention in Washington, D.C.:

"Earnest people on the Hill, in both houses, have gotten behind a bill to create a 'peace' academy. In my opinion, they are too late. Exactly 182 years too late. We established the first peace academy in America on the banks of the Hudson at West Point, New York in 1802, and we call it the United States Military Academy. It and the other academies have just one purpose—peace.

"If we're going to raise a generation of negotiators and appeasers, a generation of Neville Chamberlains who think they can acquire peace through capitulation and without strength, I hope they will remember the words of Konrad Adenauer, who said that an infallible way of appeasing a tiger 'is to allow oneself to be devoured.'

"Major civic buildings usually have plaques. I hope the Academy of Peace, if there is one, places at one side of the entrance a plaque bearing the words of Lenin: 'It is inconceivable for the Soviet republic to exist alongside the imperialist states for any length of time. One or the other must triumph in the end. And before that end comes, there will have to be a series of frightful collisions between the Soviet republic and the bourgeois states.'"

James M. Beggs, NASA Administrator, speaking at the NASA/National Academy of Sciences Symposium on Lunar Bases and Space Activities of the 21st Century in Washington, D.C.:

"The Lunar Base Working Group meeting last April at Los Alamos (debated) the pros and cons of establishing a permanently manned base on the moon's surface (and) concluded that such a base should be adopted by NASA as a long-term goal for the 21st century.

"This goal has long been our vision, and still is. Even before Apollo, our studies concluded that such a base could serve a facility for scientific research, economic exploitation of the moon's resources and colonization of the moon ...

"I believe it highly likely that before the first decade of the next century is out we will, indeed, return to the moon. We will do so not only to mine its oxygen-rich rocks and other resources, but to establish an outpost for further exploration and expansion of human activities in the solar system, in particular on Mars and the near-Earth asteroids."



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PRESIDENT • Karl G. Harr, Jr.

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OF PUBLIC RELATIONS • David O. Schillerstrom

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EDITOR • John F. Loosbrock

ASSOCIATE EDITORS • James J. Haggerty

Ellen Kelly

Jean Ross Howard

ART DIRECTOR • James J. Fisher

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On the cover: Vanes guide the airflow around corners in a 16-foot wind tunnel at Arnold Engineering Development Center (see page 10).

The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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NASA's SPACE COMMERCIALIZATION POLICY

This issue of *Aerospace* highlights a report on the outlook for space commercialization, concluding that there is great promise in exploiting space but it is too early to quantify the promise, due to a number of influencing factors whose outcome and impact are not now accurately measurable. Among those factors are acceptance of the space commercial potential by the financial community, corporate willingness to commit resources in high-risk ventures and, most importantly, government policies with respect to support of industries interested in commercializing space.

In November, NASA detailed the planned policy direction of the U.S. government with announcement of its Commercial Use of Space Policy, a follow-up to President Reagan's July statement on National Space Policy, in which he made the expansion of private investment and involvement in space a major objective.

Private investment in space, says the NASA policy statement, is expected "to yield important economic advantages; advance science and technology; help maintain U.S. space leadership; and enhance the nation's competitive position in international trade." The statement adds:

"Opportunities for benefiting the nation are significant. Commercial space endeavors offer the potential for new industries, new jobs, lower product costs and an improved balance of trade. Technological advances from commercial use of space could help conquer disease, produce computers faster and smarter than presently exist, develop metals lighter and stronger than any presently known, increase communications and information availability around the world and enhance our understanding of the environment and its resources."

The NASA document lists a series of initiatives to reduce the risks of doing business in space and thus encourage private investment.

To reduce *technical* risks, NASA will support research aimed at commercial applications, ease industry's access to NASA facilities, establish flight opportunities for commercial payloads, expand availability of technological information of commercial interest, and support development of new facilities for commercial uses of space.

To reduce *financial* risks, NASA will continue to offer reduced-rate space transportation for high-technology endeavors, assist in integrating commercial equipment with the Shuttle, provide seed-funding to stimulate space ventures and—under certain circumstances—buy commercial space products to provide an initial market.

The policy statement lists five guiding principles:

- The government should establish new links with the private sector, broadening its traditional association with the aerospace industry and the science community to include relationships with major non-aerospace firms, academia and the financial community.
- Regardless of the government's view of a project's feasibility, it should not impede private efforts to undertake space ventures.
- If the private sector can operate a space venture more efficiently than the government, such commercialization should be encouraged.
- The government should invest in high-leverage research and space facilities which encourage private investment. However, the government should not expend tax dollars for endeavors the private sector is willing to underwrite.
- When a major government contribution to a commercial endeavor is requested, two requirements must be met: the private sector must have significant capital at risk and there must be significant potential benefit to the nation.

This policy, says the statement, "will give new impetus and importance to traditional space efforts. At the same time, the policy will give private enterprises the extra push they need to get started with permanent, self-sustaining, tax revenue-producing establishments that will generate unique goods, well-paying jobs and new outlets for ingenuity and innovation in space and on the Earth. The rewards can be immense for our nation."

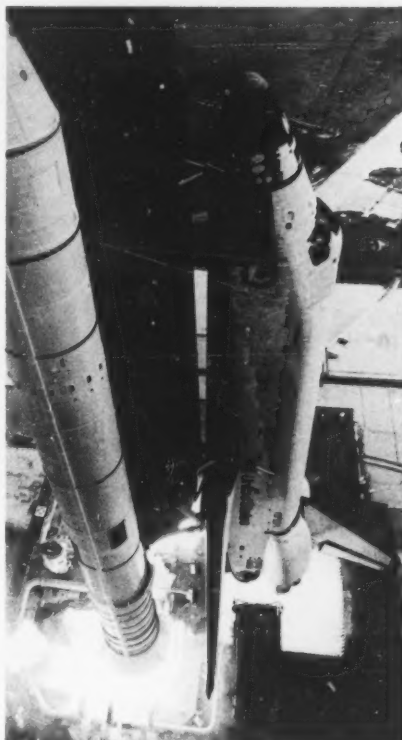
THE OUTLOOK FOR SPACE COMMERCIALIZATION

October 1984 marked the 20th anniversary of the formation of the International Telecommunications Satellite Organization (Intelsat), the world's first commercial space enterprise. Which is by way of pointing out that space commercialization, widely heralded as an economically attractive prospect for the future, has in fact been a going and ever-expanding operation for two decades. Over that span, Intelsat has grown into an organization of 109 member nations whose 15 high-capacity satellites handle more than two-thirds of all international telephone communications and virtually all overseas television. There have also emerged a number of domestic and regional commercial satellite networks, along with separate systems for such specialized purposes as business data transmission and maritime communications. In addition to these operational entities, whose combined annual revenues approach \$2 billion, there is a robust, innovative segment of the aerospace industry manufacturing satellites and ground equipment at the rate of about \$1.5 billion a year.

Commercial space activities have so far been largely confined to communications—but not entirely. In recent years, there has been increasing commercial use of Landsat remotely-sensed data, for example by oil companies to identify areas that might contain petroleum deposits and by paper companies for more effective management of their forest land. Since the latter 1970s, McDonnell Douglas Corporation has been selling the world's first commercial space booster, an upper stage system that has launched 20 satellites. Since 1980, the French-dominated European space transport company—Arianespace—has been offering commercial launch services. Space manufacturing research has been under way for more than a decade and the first made-in-orbit product will soon be available for sale.

So space commercialization is not something new. What is new is the opportunity for vastly accelerated activity in all these areas, occasioned by a variety of factors. Projections indicate greatly expanded demand for space-based commercial communications services, which will in turn require increased production of both satellites and launch systems. A government decision to turn the Landsat system over to a commercial operator,

By JAMES J. HAGGERTY



coupled with plans to improve collection and dissemination of information from the satellites, should spur greater commercial use of remotely-sensed data. The availability of the Space Shuttle, which makes possible Earth-returnable experiments in materials processing, is a major stimulant to corporate interest in space manufacturing; and the planned space station, which will house permanent facilities for manufacturing operations, represents an even greater stimulus. In addition, the government has stated a policy under which it would provide a broad range of economic and other incentives intended to reduce the risk of commercial space ventures and stimulate private sector investment.

That policy stemmed from recognition—by both the Administration and the Congress—that commercial space activity promises “immense benefits” and is essential to continued U.S. leadership in science, technology and trade. The governments of other free world industrialized nations are similarly aware of

the potential and a number of them—notably France, West Germany and Japan—are aggressively pursuing it.

Will the immense benefits actually materialize? Our national impatience demands answers before the facts are available and there are many willing to supply them. Some see a space commercial boom of enormous dimension; others suggest it is a pleasant fantasy that will provide at best limited economic or societal benefit.

Such views are based more on intuition than fact. In the first place, it is difficult to forecast space commercialization in general terms, because there are several different areas of commercialization and each has a different set of problems and prospects. Additionally, there are many influencing factors that affect each of these areas, factors whose outcome and impact are not now accurately measurable. They include such considerations as the extent to which governments will back their spacebound industries, not only with policies but with direct support and financial incentives; greater awareness and acceptance of the space potential by non-aerospace industries; company willingness to invest technical and monetary resources in high-risk, distant-payoff ventures; acceptance by the financial community; development of markets for space products and services; and a great deal of advanced research to confirm that many theoretically attractive space projects are in fact economically viable. The next decade should provide a clearer view of whether these factors amount to real barriers or just low hurdles.

In the meantime, consensus of the most informed opinion leans toward the optimistic view. For example, The Center for Space Policy, a Cambridge, Massachusetts organization that specializes in evaluating space commercialization opportunities, predicts—by year 2000—annual revenues of \$65 billion. And NASA Administrator James M. Beggs, the man best positioned to venture an opinion, sees cumulative revenues by 2000 in the hundreds of billions.

The following pages contain an illustrated summary of the status and outlook for space commercialization in five major areas of activity: space-based communications, remote sensing of Earth resources, ground launch vehicles, upper stages and space manufacturing.

SATELLITE COMMUNICATIONS

Demand for space-based communications relay has been increasing rapidly in recent years and will probably continue to do so despite some potential retardants. The first transatlantic fiber-optic cable is scheduled to go into operation about 1990; featuring very high transmission capacity and low cost, it poses a strong competitive challenge to satellite communications carriers. Crowding of the synchronous orbit where satcoms operate also threatens to limit availability of orbital positions.

Communications carriers look to advancing technology to meet the latter difficulty. Government research agencies and satellite manufacturers are developing advanced technologies that will allow greater numbers of transponders per satellite, more effective employment of existing wavebands, and transmissions in a new band not yet in use—all combining to permit very large gains in individual satellite capacity.

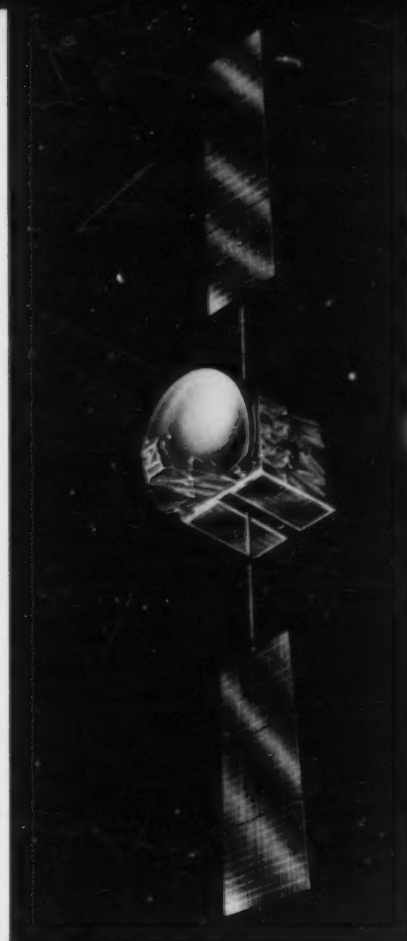
Such advances should also improve satellite operators' ability to compete with the upcoming cable system. Further, fiber optic cable transmissions will have their greatest competitive impact on international communications. There remain the large domestic and regional markets, particularly in the U.S. and Canada, continually expanding under the impetus of such new services as video teleconferencing, computer-to-computer linkages for business use, direct TV broadcast to home receivers and—the next step—mobile communications for truckers, railroads, fire, ambulance and rescue services, operators of small aircraft and private autos.

So, although cable competition may have a growth-limiting effect on the international segment of the space communications industry, the overall picture is bright. One study estimates that the number of transponders in orbit at the turn of the century will be up to five times the current figure. The Center for Space Policy sees, by the year 2000, space communications revenues of \$15 billion annually, which would amount to a four-to-fivefold increase.

It seems likely that U.S. firms will capture the bulk of the revenues, because American companies have dominated both the satellite operating and satellite production segments of the industry. The U.S. Communications Satellite Corporation (Comsat) is the major entity in the 109-nation Intelsat consortium and Comsat subsidiaries are engaged in a variety of domestic and specialized services. Among other major operators are AT&T, ITT, IBM Corporation, GTE Corporation and Western Union, together

with subsidiaries of Hughes Aircraft, RCA Corporation and Ford Aerospace, the Big Three of commercial satellite production. The Big Three have built all but a few of the more than 100 active commercial communications satellites in orbit.

But, since communications systems in Western Europe are operated by government postal-telephone-telegraph agencies (PTTs) committed to "buy national" policies, U.S. manufacturers are barred from the European market. A consortium of PTTs operates the European regional Eutelsat system; the satellites, developed under the aegis of the European Space Agency, are built by a British-led multinational group that includes French, German and Italian participation. Each of the latter nations is also building—or planning—a domestic satellite system to be built by its own industry. Japan has already launched a series of communications satellites and is developing a new, advanced-technology, high-capacity satellite. Canada is pushing a domestic mobile satellite communications system, which will become a North American system with U.S. participation. So there is—or will be—plenty of competition for U.S. manufacturers, but competitors will have a tough time overcoming the U.S. lead.



One of the most advanced communications satellites is Spacenet, built by RCA for GTE Spacenet Corporation; the first of three was launched last May.



This photo illustrates the dramatic increase in satellite size and capacity over two decades of satcom development: at bottom, Hughes Aircraft's 1965 Intelsat I, above it Hughes' new Intelsat VI targeted for 1986 launch.

EARTH REMOTE SENSING

Many familiar with the potential of space-based sensing of Earth's resources feel it has commercial possibilities of enormous order. The problem is that most of the world's business and government organizations that might use the technology to advantage are only vaguely or not at all aware of the potential.

Satellite remote sensing's broad utility stems from the fact that every Earth feature emits or reflects a different type of radiation, producing an identifying "signature" that can be detected by space-based sensors. Thus, satellite data can be computer-processed to differentiate among surface features and provide voluminous information that can be put to practical use in many ways; about 80 useful applications have been identified.

The U.S. Landsat system, the only one in operation, is providing data to many state and local governments, who use it in such applications as land use planning, tax assessment, parkland survey, pollution control and coastal zone management. It is also being used by business firms in oil exploration, mineral prospecting, mapping, agricultural crop forecasting and commercial forest management. A small industry has emerged, composed of companies providing ground-use equipment for processing remotely-sensed data and others that offer data processing and analysis services to users who do not care to invest in their own equipment.

NASA developed and operated five Landsat satellites—built by General Elec-

tric's Space Systems Division—from 1972 until 1983, when the system was turned over to the National Oceanic and Atmospheric Administration of the Department of Commerce. With that experience and a solid user/supplier base, one might think that the U.S. has a very big lead in international competition. Such is not the case; in fact, it seems likely that the first truly commercial provision of remote sensing data—as opposed to the current government-provided service to commercial users—will be offered by a European group, the French-led SPOT Image Corporation. Other European and Japanese ventures are in development. In commercial remote sensing, foreign competitors see a good opportunity for leapfrogging the U.S. lead and they are going for it.

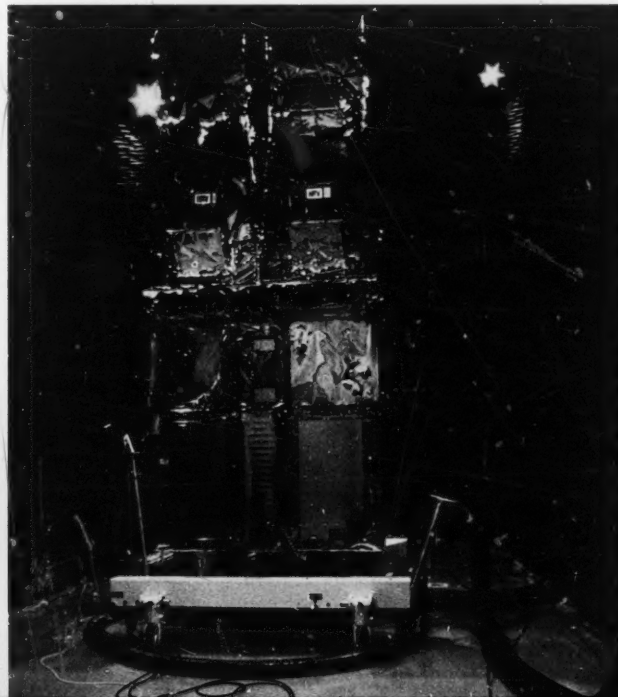
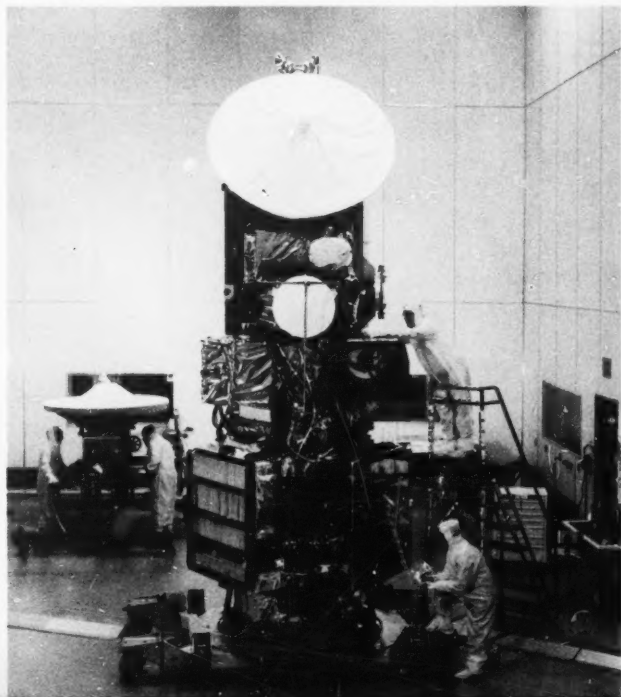
They got encouragement this year when U.S. plans to commercialize the Landsat system snagged. Congress authorized the Landsat transfer in July and subsequently, after evaluating several proposals, Commerce selected as the system operator Earth Observation Satellite Company (EOSAT), a joint venture of Hughes Aircraft Company and RCA Corporation. Under the agreement, the government was to provide \$250 million, spread over several transitional years, for operation of the already-in-orbit Landsat 5 and for development and launch of a follow-on Landsat 6 in 1988. EOSAT was to build a ground station for processing and marketing Landsat imagery and eventually—after 1990—operate the system on its own and fund develop-

ment of an advanced Landsat 7. But the Office of Management and Budget blocked the Administration's request for the transitional funding, so the U.S. commercialization program has stalled while the competition is moving rapidly.

SPOT Image is readying its first SPOT (Système Probatoire pour Observation de la Terre) satellite for launch next year and is conducting an aggressive marketing campaign. A second European group, the German-led SPARX project—which has American participation—has a competing system in advanced development. Japan has embarked on an ambitious program involving development of two separate types of land observation satellites for service beginning in 1986. Both Japan and the U.S. (NASA) are working on ocean-imaging satellites that could become commercial systems in the 1990s, expanding remote sensing activities to include valuable services to fishing and shipping industries and to government agencies concerned with such matters as coastal storm warning and maritime safety.

Commercial competition in remote sensing is expected to generate new techniques for improved data processing to make data more useful more rapidly, and to promote greater public awareness of the remote sensing potential. Successful efforts in those directions could mean end-of-the-century revenues on the order of \$2 billion annually, according to an estimate by The Center for Space Policy.

The leading contenders in remote sensing satellite competition: at left, the GE-built U.S. Landsat 5, launched in March 1984; at right, the European SPOT system, to be launched next year.



Courtesy CNES (France) SPOT Image Corporation

LAUNCH VEHICLES

For almost 20 years, the U.S. enjoyed a monopoly in providing launch services for commercial satellites. The monopoly ended last May when the European Space Agency's Ariane, after eight development flights, launched its first commercial payload under the aegis of Arianespace, the French-led commercial space transportation company. More recently, Arianespace introduced the more powerful Ariane 3, which delivered two communications satellites to orbit on an August launch.

Arianespace is proving to be a formidable competitor to the U.S. Space Shuttle. At last count, the company had firm orders for launching 26 satellites, a backlog worth some \$875 million; it is developing a more advanced Ariane 4, intended for operational service in 1986, and France recently proposed to its ESA partners development—at a cost of more than \$1 billion—of an Ariane 5 capable of delivering the heaviest payloads anticipated in the 1990s.

On the horizon is more foreign competition. Japan has in the works a medium-size H-1 vehicle, planned for service in 1988, and an advanced, heavy-lift H-2 booster designed to compete for international business in the 1990s.

In October, the Congress opened the door to a new phase of U.S. space commercialization by passing the Commercial Space Launch Act, designed to encourage growth of a U.S. launch indus-

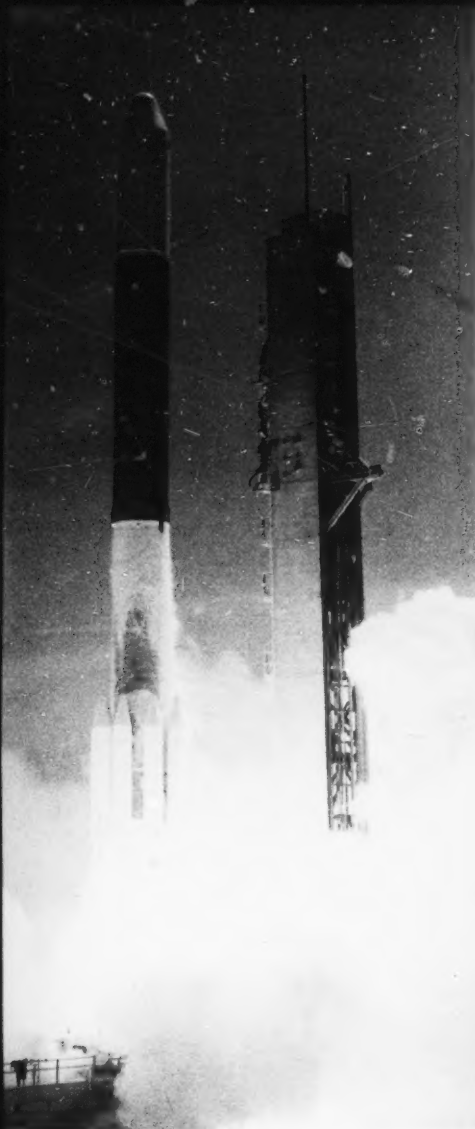
try. The law designates the Department of Transportation as the lead agency for approving private space launch operations with government-developed expendable launch vehicles (ELVs) now operated by NASA and the Air Force; it also authorizes DoT to license use of government launch facilities on a reimbursable basis and charges DoT with regulating launch safety.

Transpace Carriers Inc. is negotiating with NASA for commercial marketing and operation of the workhorse Delta vehicle, built by McDonnell Douglas Corporation. General Dynamics Corporation, prime contractor for the larger Atlas/Centaur, has submitted a proposal for commercial production and launch of that system. Another possibility for commercialization is the Martin Marietta-built Titan 34D, largest of the U.S. ELVs. And, before year-end, NASA is expected to solicit proposals for commercialization of the relatively small Scout ELV; several companies, including Scout builder LTV Aerospace, have expressed interest. In addition, NASA is weighing a proposal by Astrotech International under which the company would fund construction of a fifth Space Shuttle Orbiter for commercial operation.

NASA uses the term "privatization" to describe transfer of these launch vehicles to private builders/operators. The distinction between privatization and commercialization is that the former term applies to vehicles already developed to a high-degree of reliability under government funding; thus, privatization involves less risk to entrepreneurs and merits less government support than commercialization.

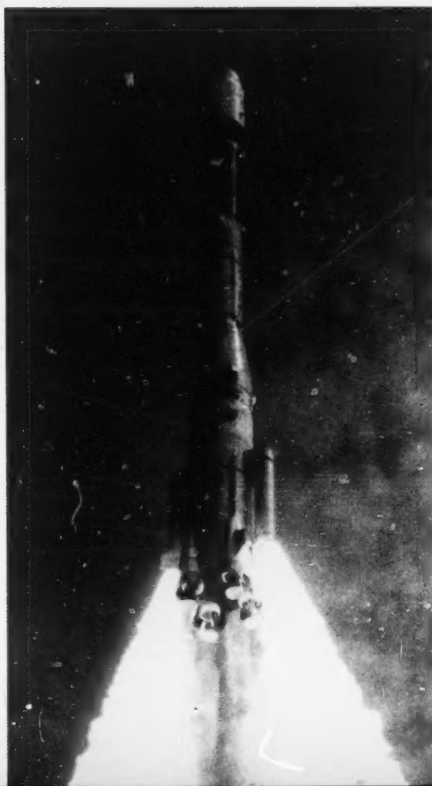
There are, however, launch vehicle projects that were designed from the beginning as commercial ventures. One is the Conestoga booster for small payloads, designed by Space Services, Inc. of America; the company successfully launched a prototype Conestoga 1 in 1982 and is developing a family of more advanced versions. Another company—Starstruck, Inc., currently undergoing reorganization—launched its Dolphin sounding rocket in August; the Dolphin is the first step in a plan to develop an orbital launch vehicle designed for the communications satellite market. Other U.S. firms have announced plans for launch vehicle developments but have not reached hardware status.

The outlook for U.S. commercial ELV operation is difficult to assess, since operators must compete with both Ariane and the Shuttle. The Center for Space Policy estimates annual revenues by year 2000 of \$1 billion—for all commercial boosters.



Veteran of more than 170 launches, the McDonnell Douglas/NASA Delta is a prime contender for commercial operation.

Newest of the Ariane family—Ariane 3—entered commercial launch service in August.



UPPER STAGES

An upper stage, also known as a transfer orbit stage or a payload assist module, is a secondary booster employed to propel satellites to high altitude orbit or deep space trajectory. The Space Shuttle Orbiter, for example, operates by design at altitudes below 700 miles, so Orbiter payloads destined for geosynchronous orbit (22,300 miles) are deposited in low Earth orbit affixed to an upper stage propulsion/guidance system that propels the satellite to its requisite high altitude position. Upper stages are similarly employed with expendable launch vehicles (ELVs).

The first commercial upper stage was the PAM (Payload Assist Module) developed by McDonnell Douglas Corporation with company funding. PAM was initially developed in two versions, one for use with the McDonnell Douglas/NASA Delta ELV and another for Shuttle launch. Powered by Morton Thiokol solid rocket motors, the two types of PAMs have successfully launched 20 satellites, their record marred only by failures on a February 1984 Shuttle flight when two satellites were sent into wrong orbits.

McDonnell Douglas is developing two larger versions for delivering larger satellites: a PAM-DII for Shuttle use and a PAM-A for use with Atlas; both will be ready for service next year. In cooperation with Astrotech International McDonnell Douglas is also developing an upper stage based on the second stage of the Delta vehicle.

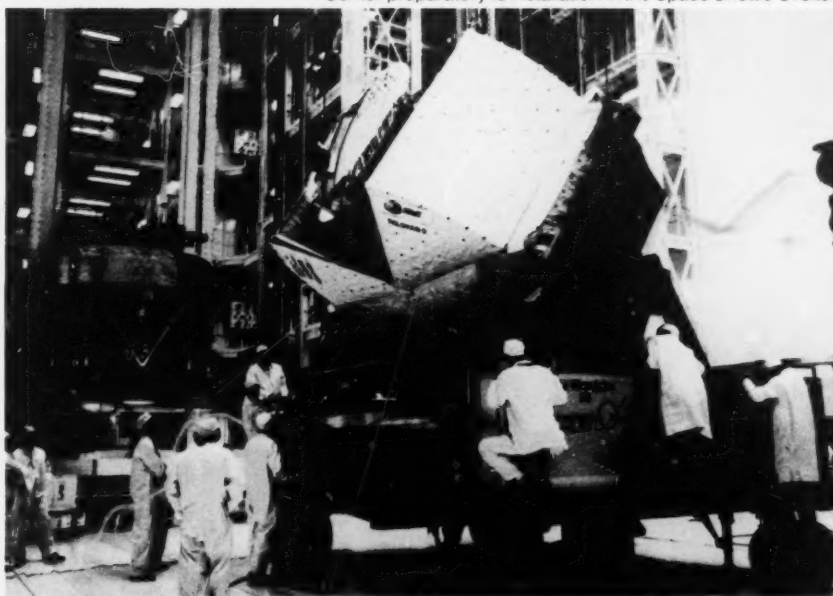
NASA and the Air Force are also using the Boeing-built Inertial Upper Stage for heavier payloads and are developing advanced versions of the General Dynamics Centaur for even larger payloads. Neither has commercial assignments because their heavy-boost capabilities are not needed for current generation commercial satellites, but both have commercialization potential for the future, when satellites get bigger.

Several companies are planning or considering development of upper stages but only one other has moved as far as hardware status: Orbital Sciences Corporation (OSC). Formed in 1982, OSC is a financing/marketing firm which has raised some \$95 million for initial funding of four Shuttle-use systems. They include

the medium-capacity Transfer Orbit Stage (TOS); a shortened version for smaller payloads, the TOS-S; an Apogee and Maneuvering Stage (AMS); and the TOS/AMS, a two-stage system for boosting large payloads. For development and construction of these systems, OSC has teamed with several space-experienced aerospace companies: Martin Marietta Denver Aerospace, prime contractor; United Technologies' Chemical Systems Division, TOS solid rockets; Aerojet Technical Systems Company, AMS liquid rockets; Honeywell Inc., avionics; and Lockheed Missiles & Space Company, stage separation.

In development by each of the Big Three communications satellite manufacturers—Hughes Aircraft, RCA Corporation, Ford Aerospace—is the integral upper stage, a self-contained boost system that would obviate the need for a separate upper stage in launching some types of satellites. This technology clouds the market potential of the McDonnell Douglas and OSC systems, but both companies express optimism. McDonnell Douglas sees 75 firm or potential missions for its PAMs over the next seven years. OSC's market assessment projects a total demand for 250 to 300 launches through 1995.

Its clamshell doors encasing a Telstar satellite, a McDonnell Douglas PAM upper stage is unloaded at Kennedy Space Center preparatory to installation in the Space Shuttle Orbiter.



A new entry in the commercial upper stage competition is Orbital Sciences Corporation's two-stage TOS/AMS. The TOS (Transfer Orbit Stage) is the lower unit; the AMS (Apogee and Maneuvering Stage), shown mated to a satellite, delivers the final kick into orbit.

SPACE MANUFACTURING

The first commercial products made in space will go on the market soon. They are latex "microspheres", about one billion of them, of perfect spherical uniformity and all exactly the same size—one hundred thousandth of an inch in diameter. They are used by research and industrial laboratories for instrument calibration and other applications in the field of medicine, oil, chemicals, glass and metallurgy. Such spheres fill a long-standing need because they cannot be produced on Earth in the sizes laboratories want, due to the effects of gravity. NASA made the spheres on five Shuttle flights and turned them over to the National Bureau of Standards for certification, packaging and sale.

Microsphere production is not the most dramatic example of the space manufacturing potential, but NASA undertook the project to demonstrate the utility of space materials processing and encourage broader interest in this technology, which allows production of a great range of items not producible on Earth because of the adverse effects of gravity and air.

The most notable effort thus far is the Electrophoresis Operations in Space

(EOS) program conducted by McDonnell Douglas Corporation and its EOS partner Johnson & Johnson. The EOS project is aimed at separating biological materials—cells, enzymes hormones and other proteins—in sufficient quantities and purities to enable production of pharmaceuticals for more effective treatment of many diseases. In Shuttleborne tests, the EOS system demonstrated its ability to produce more than 700 times the material that could be extracted from similar Earth processing, with a fourfold increase in purity. McDonnell Douglas and Johnson & Johnson hope to make their first pharmaceutical product available for public use within this decade.

In addition to pharmaceuticals, there are a great many other possibilities, for example, silicon crystals with enormously improved electrical properties, offering great advances in electronics; extremely pure glass for such applications as lasers or optics; and vastly superior metallic alloys for a multitude of uses.

Major manufacturers are gradually becoming more aware of the space manufacturing potential. Many, including such big names as Alcoa, General Motors, Union Carbide and Westinghouse—are conducting studies and ground experiments with an eye toward actual space research. About a score of companies have already signed or are negotiating agreements with NASA for orbital research. For example, 3M Corporation, already engaged in space experimentation, is negotiating a product development program involving as many as 72 Shuttle flights over the next 10 years. The farm equipment firm Deere & Company is also involved in space research, but with a different perspective: Deere

has no plans to manufacture products in space, but wants to study iron processing under weightless conditions with the aim of developing new Earth processing techniques for improving the strength and quality of cast irons.

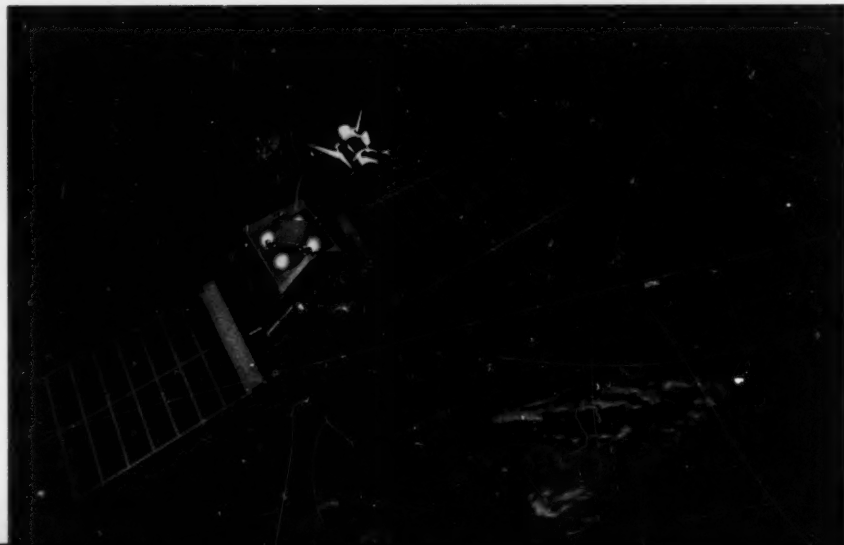
A number of companies are pursuing another line of commercial opportunity: producing furnaces and other processing equipment for sale to researchers. One company—Bali Aerospace—is developing a complete Shuttle-based materials processing plant. Fairchild Industries, in cooperation with NASA, is developing a free-flying platform to support a Shuttle-tended orbital factory; called Leasecraft, it is targeted for flight in 1988.

Studies indicate that there are some 500 materials that could be advantageously processed in space. How many of them will result in viable commercial products remains to be seen; similarly, there is question as to how many industrial firms will commit to large-scale research outlays toward products of uncertain marketability. But the ranks of space-interested companies are already swelling under the impetus of the McDonnell Douglas/NASA pioneering efforts. The prospective availability of a space station with permanent research/manufacturing facilities should spur greater interest. McDonnell Douglas forecasts sales of \$1 billion a year, by the mid-1990s, for its initial drug product—and the company hopes to be processing as many as 10 new pharmaceuticals by the end of the century. The Center for Space Policy sees annual revenues—by year 2000—of more than \$40 billion in pharmaceuticals (\$27 billion), space-processed glass (\$11.5 billion) and semiconductors (\$3.1 billion).



McDonnell Douglas engineer Charles D. Walker, who became the first commercial astronaut last August, is shown calibrating the EOS materials processing system carried on the mid-deck of the Shuttle Orbiter.

Fairchild Industries' Leasecraft, planned for first flight in 1988, is a Shuttle-retrievable orbital platform designed to support space manufacturing operations.





By MALCOLM T. STAMPER
President, The Boeing Company

Malcolm T. Stamper joined The Boeing Company in 1962 after 14 years with General Motors. Initially he directed the company's aerospace electronic operations; later he served as general manager of the Turbine Division, general manager of the Boeing 747 Division, general manager of the Commercial Airplane Group, and corporate senior vice president-operations. In September 1972 he was elected president of The Boeing Company and a member of the board of directors. He also serves on the boards of the Smithsonian Associates, The Nordstrom Company, The Travelers Insurance Companies and Chrysler Corporation. This article is excerpted from his speech at the NASA Symposium on Productivity in Washington, D.C.

We're improving productivity in the aerospace industry. Not as exciting, perhaps, as touching off the first moon rocket, but it's vital if we're to home-stead the space frontier. The aerospace industry is also the sturdy foundation for our Triad national defense strategy—our submarines, B-52s, and Minuteman missiles. In these, as in all our military products, we have a very low tolerance for failure. We in aerospace have our own "triad strategy"—performance, reliability, superiority. Coming in second in a bi-polar world clearly isn't useful. Being Number One is not a goal—it's an imperative.

Pride in American aerospace runs deep. We employ 1,200,000 people and jobs are on the rise. We have 100,000 scientists and engineers doing research and development, nearly 20 percent of the national total. Sales last year exceeded \$75 billion—2.3 percent of the Gross National Product. Our industry's backlog is \$120 billion. And at a time when our nation's trade deficit is at an all-time high, we can be proud that our industry is part of the cure, not the cause. We contributed a positive \$12.6 billion to America's balance of trade last year. As an industry we paid \$1.7 billion in federal, state, and local taxes last year, contributed millions to the communities

where we work and invested \$5.5 billion in new plants and equipment.

Our industry is part of the reason why American business productivity continues to grow at a healthy rate—4.7 percent in the second quarter of this year, the eighth quarter in a row and the longest string of productivity increases in a decade.

Our track record is good. We have the right stuff. We have the ingredients not only for improving but sustaining high productivity. America is rich in the assets that count: a free society, immense natural resources, industrial maturity, a proven reputation for innovation, unexcelled technical competence, and confidence, born of experience, that the sky is no limit to progress.

So in America we have the resources, we have the leadership and we have the people—especially the people—capable of creativity, high productivity and uncompromising quality. Quality and productivity go hand in hand—the more we improve quality, the lower our costs are going to be.

We are all responsible for making the product better, improving productivity and working "smarter". And instead of executives looking to Washington and labor looking to the board rooms and the public looking to their elected officials, the truth is that when it comes to improving productivity, we should all look to ourselves first.

As Ruben Mettler of TRW said recently: "In the arena of global competition, the battle is no longer just between industry and industry, or company and company, each seeking a comparative advantage largely on its own. Being competitive today is a matter of what society does: it is government, managers, employees, unions, educational institutions, consumers and taxpayers—all together, all part of the action." Let's take a look at the initiatives to improve productivity that each of us can take—government, management, employees, newsmen and the public.

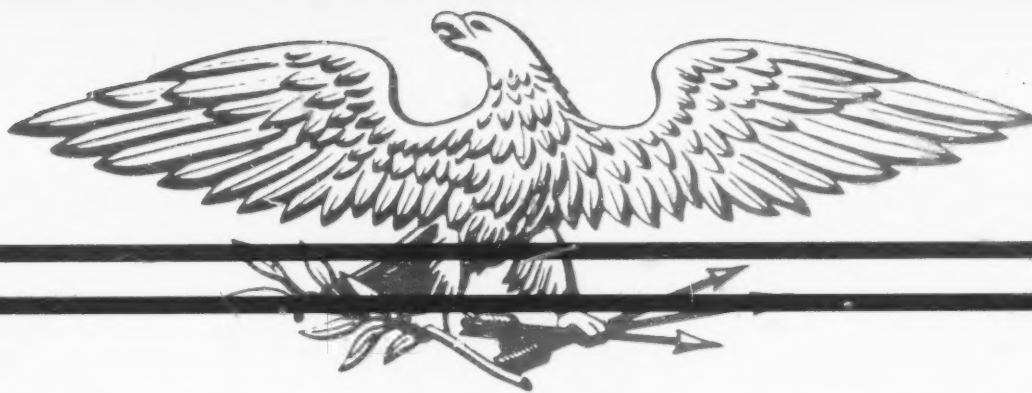
Government Initiatives

First, government itself has responsibilities to enhance productivity. It needs to sponsor research and development, enact effective tax legislation, promote export incentives and develop progressive international trade policies, stimulate competition and keep a tight rein on regulation, carry out a balanced monetary policy and reward investment. Government does not owe American industry a living, but it is charged with the responsibility of developing an environment where business can compete fairly, operate efficiently, and invest with confidence for the future. Government needs to encourage statesmen who are sensitive about the power they've been given over the institutions of our society and who don't easily tear them down on flimsy evidence and incomplete facts—sacrificing honest effort for political expediency.

Management Initiatives

Second, management's role in improving productivity is critical. Management functions at the front lines of risk, product development, research and development, market growth, and employee motivation in an environment of ever-changing ground rules. It must provide the facilities and tools that speak to productivity—and be ceaseless in its search for better ways to make things. It must set an example by practicing fairness and proper constraint in executive compensation. Management must be willing to take the "Big Risk".

The ground rules in business, as we know, change. Virtually a company's sole report card not too many years ago was the "bottom line"—dollars and cents, profit or loss. That attitude doesn't go very far today. Not that profit isn't important; we have the stockholders' word on that. But the bottom line for world class companies today is more complicated. It's now a composite—in part financial, of course, but also required to take into account environmental, social, and human values as well.



Employee Initiatives

Thirdly, for all that government and management do, our employees remain the key in our quest for new pinnacles of productivity. The \$3,514,900 in suggestion awards that our Boeing employees earned last year on 16,547 suggestions speak to that. Yet interestingly, we still fall short of the average Japanese industrial worker who turns in 25 suggestions per year. Our employees will take an increasing personal interest in the welfare of our companies when we give them the opportunity, encouragement, and reason to do so. They'll produce when motivated!

Newsmaking Initiatives

And fourthly, there is yet another element to the productivity equation—one we might not usually consider. I refer to those who report the news, the watchdogs of our society.

All of us who have felt the sting of an incomplete story sense the frustration of trying to achieve the balance we feel is due. Yet, as companies receiving public dollars, we know we operate in a "fish-bowl" environment, and that we need to be accountable not only to our stockholders but to the American people. We must not only be upright and productive, we must be *perceived* in that light.

we take in our performance, the confidence we have in ourselves and in the morality of our motivations. America has always been a productive society. We've led the world in this area since the beginning of the industrial revolution and have known we were good—everybody sensed it. But has doubt crept in? Have the people who report the news, who are just as competitive as every other industry, and seek the "big story," have they relentlessly exposed every infraction, every failure, every weakness, till perhaps we are no longer sure of ourselves or the purity of our motives? The need for free speech and open forums is sacred to our free society and not negotiable, but opinion versus fact—and balance of story—perhaps are.

What I'm suggesting is an initiative by the newsmen to look beyond the headline, to see every story in perspective. Not to *fail* to report to the American people, but to report the positive along with the negative, so that the end result thereby, demanded by the public, is not more costly to our taxpayers or our security—that the cure isn't worse than the disease. Perhaps, then, the concept of a "balanced story" must reach out further, take in more ground, require more work and thereby be more useful to society and help render us more productive.

Public Initiatives

Lastly, the public also has a part to play in making our society more productive. The people, in the final analysis, determine where taxes are spent, what problems they want fixed, what course our laws take, and what programs merit federal support because they choose who's to govern us. But in saying this, let's remember who the public is. They are management, newsmen, employees; the people we buy from and sell to; passengers on our planes; and citizens of our communities. A cross-section of America, subject to the same interests, concerns, and ambitions we all share. The public is not "they." The public is

My concern is this: that in their zeal, those who report the news may in fact be inadvertently endangering the pride "us." We all have a vested interest in making America work better and smarter. We will be successful when we are bound together in mutual trust, when we realize that the people who are both making and using the systems to defend us, are American citizens too—that the 1,200,000 aerospace workers in America are on our side and we should not be so ready to write them off because of a glib story or two about a hammer, a stool cap or a coffeemaker. Instead, we're going to also look at what they have done right and not just what they haven't done right. Their performance can stand the test.

Less than a century ago one of America's premier inventive geniuses—Thomas Edison—dismissed aviation as impractical. "It is apparent to me," he said, "that the possibilities of the aeroplane have been exhausted and we must turn our attentions elsewhere."

Eighty years ago Octave Chanute, one of our first aviators, said: "Airplanes will be used in sport, but they are not to be thought of as commercial carriers."

Along with a host of other detractors, aviation pessimists down through the years have been proven wrong. Today is no different. There are those quick to count the reasons why we can no longer fly faster, higher or farther. Whatever the reasons—costs, safety or technology—their arguments defy the American tradition. As President Reagan said a few weeks ago: "There is nothing the United States of America cannot accomplish if the doubting Thomases would just stand aside."

As individuals, or as a civilization, we only go around once. Our goal should be building, not belittling. We can pull together or polarize our society—spark a renaissance or sink in despair. The profit from productivity is measured not in balance sheets alone, but in the quality and security of life in our country and on this Earth now and tomorrow.

**"The public is not 'they.'
The public is 'us.' We all
have a vested interest in
making America work
better and smarter. We will
be successful when we
are bound together in
mutual trust."**

Probing Flight Frontiers at ARNOLD ENGINEERING



Latest addition to Arnold Engineering Development Center is the 57-acre Aeropropulsion Systems Test Facility where—beginning next September—air-breathing engines of 75-100,000 pounds thrust will be tested.

The complex of ground test facilities operated by the Department of Defense, NASA and industry companies is a vital part of the U.S. aerospace research and development capability. Simulation in ground facilities does not eliminate the need for flight testing, but it sharply reduces the flight test time required and compresses total development time for a new system; most importantly, it affords significant savings in the cost of readying a system for operational service.

Ground simulation's big advantage is that the many variables of the flight "envelope" can be precisely controlled and test results fully documented by sophisticated instrumentation. Using less expensive models rather than flight hardware, researchers can expose a test vehicle to best, normal and worst conditions, test it over long durations and run it through repetitive cycles. After these preliminaries, flight tests can be conducted with far greater safety and confidence in the system's reliability.

An important addition to the U.S. ground simulation complex is the Air Force's Aeropropulsion Systems Test Facility (ASTF), dedicated in October after seven years in construction. Scheduled to begin operation next year, ASTF will enable ground test of air-breathing engines—military and civilian—two to three times the size of any currently in use. It will more than double the nation's engine test capability, providing an environment that will simulate all conditions of flight—takeoff, climb, multi-speed maneuvers, descent and landing.

ASTF is part of the USAF's Arnold Engineering Development Center (AEDC), named for General H. H. "Hap" Arnold, who was the driving force behind the center's creation. Built in 1950-53 and frequently updated by additions and modifications, AEDC sprawls over more than 40,000 acres of middle Tennessee. It is the largest and most advanced flight simulation complex in the free world, containing 40 major facilities, 27 of them with capabilities

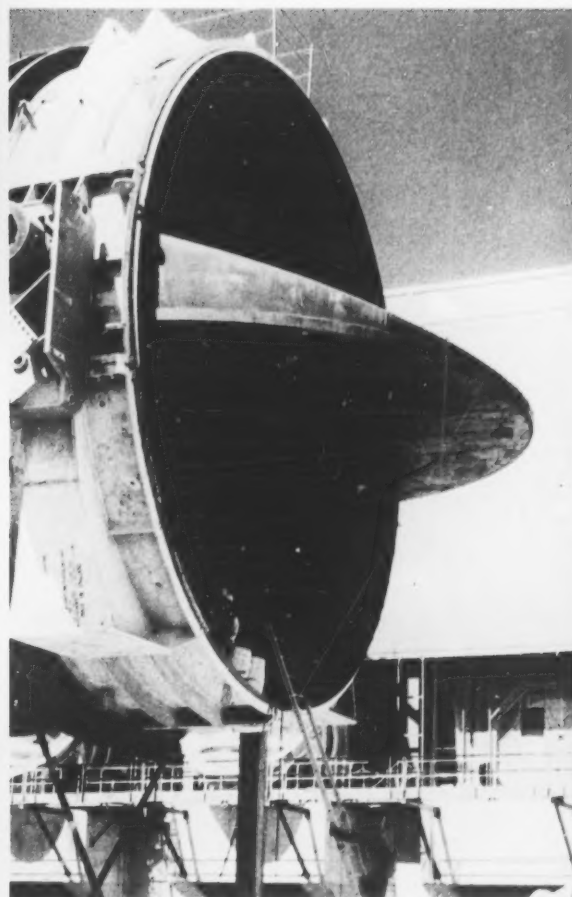
unmatched elsewhere. These facilities, which use some 325 million kilowatt hours of electricity a year, simulate flight conditions from sea level to 1,000 miles altitude, velocities, from subsonic to more than 20 times the speed of sound. AEDC's major components are:

- The Engine Test Facility, which has 11 cells for testing propulsion systems of aircraft, missiles, spacecraft and space launch vehicles. It includes the world's two largest high-altitude simulation cells, one for testing solid propellant rockets with thrust up to 125,000 pounds, the other for liquid and solid rockets up to 500,000 pounds thrust.
- The Propulsion Wind Tunnel Facility, which has two 16-foot tunnels—one transonic and one supersonic—for testing full-scale engines, large aircraft and missile models, and some full-scale missiles; a four-foot transonic tunnel for certifying that an aircraft can safely carry or release external "stores"—bombs, missiles or fuel tanks—at critical flight conditions; and a one-foot transonic tunnel used to evaluate proposed improvements to the larger tunnels.
- The Von Karman Gas Dynamics Facility, which has four high-speed wind tunnels for testing relatively large-scale aircraft/missile models at flight conditions ranging from Mach 1.5 to Mach 10; four ballistic ranges, in which models travel in free flight at velocities up to 30,000 feet per second; and four high-vacuum space chambers for testing full-scale spacecraft and subsystems.
- The Aeropropulsion Systems Test Facility, which has two large cells for subsonic and supersonic testing of the more powerful jet engines of the future—engines with thrust rating of 75-100,000 pounds—at speeds up to Mach 3.8, with airflow cooled or heated to simulate specific flight environments.

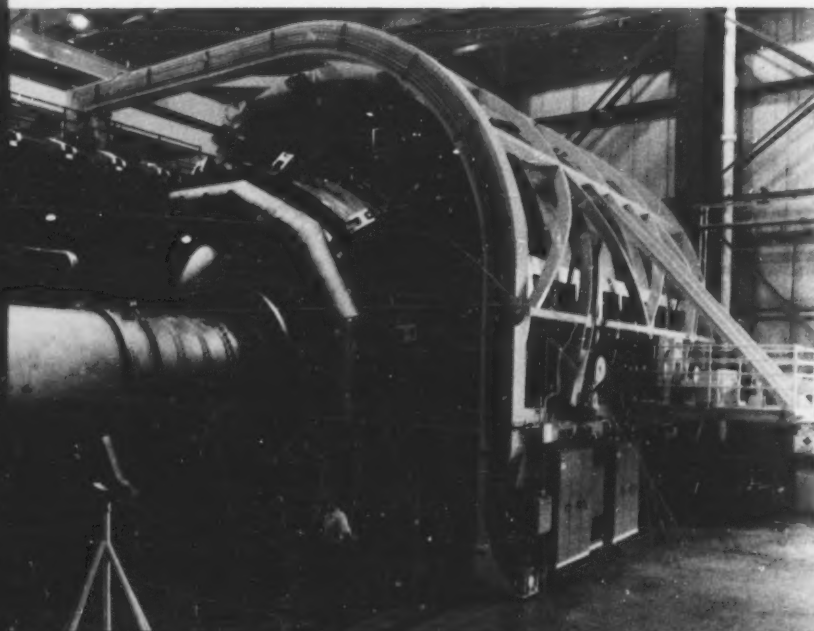
DEVELOPMENT CENTER



In the Aeropropulsion Systems Test Facility (ASTF), test airflow is drawn from the atmosphere, compressed and fed to the two largest air-breathing engine test cells in the world. The exhausters pictured, driven by 12 motors with a combined 396,000 horsepower, create low pressures within the test cells to simulate high-altitude flight; they also capture and treat exhaust gases before venting them into the atmosphere.

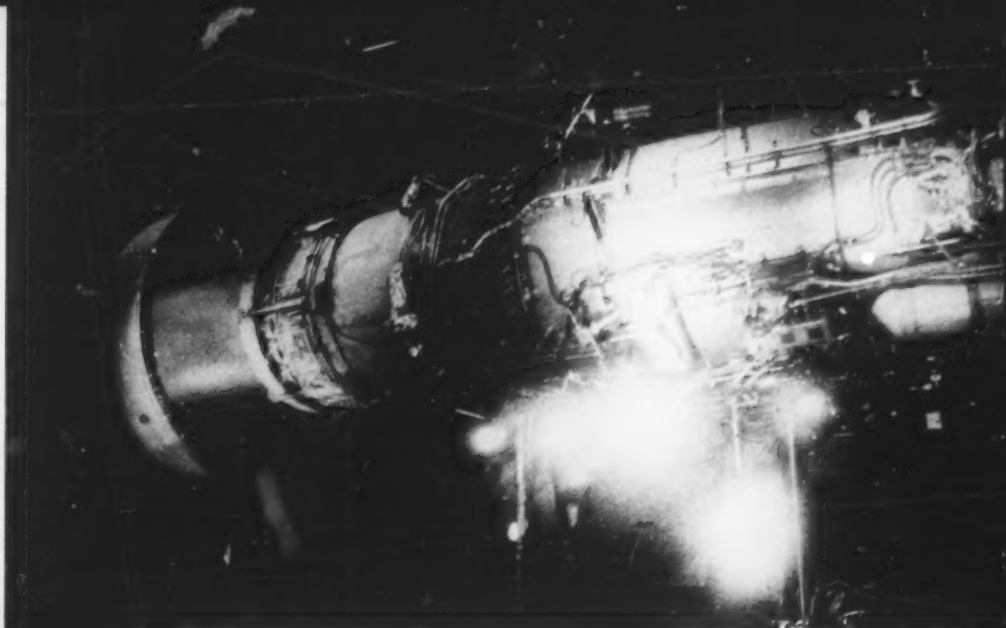


This 170-ton butterfly valve, the world's largest, isolates one bank of exhausters from another while controlling the pressure and volume through ASTF's test cells.



One of ASTF's two test cells, shown open; during a test, a 52-ton hatch covers the airflow ducting. Eighty-five feet long and 28 feet in diameter, the cell accommodates full-scale engines mounted in portions of the airframe that would affect airflow during flight.

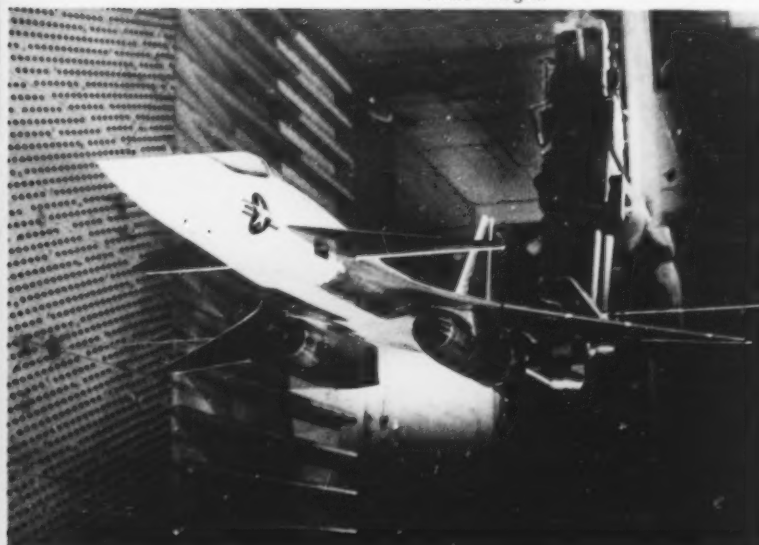
In an altitude test cell of the Engine Test Facility, a General Electric F101 engine undergoes evaluation. To simulate high altitude conditions, the airflow entering the engine's inlet was chilled to minus 65 degrees Fahrenheit. For this test, engineers simulated an altitude of 64,000 feet and aircraft speeds ranging from subsonic to more than twice the speed of sound.



Ready for test in the PWT's 16-foot transonic tunnel is a one-eighth scale model of an advanced fighter concept. This design features forward canards instead of a horizontal tail and a main wing capable of changing its aerodynamic properties in flight.



Among the 11 cells of the Engine Test Facility is the J-4 vertical test cell, which can simulate high altitude operation of rocket engines with thrusts up to 500,000 pounds. The exhaust gases come down through the large duct pictured, then are directed through a maze of cooling water spray pipes before being pumped out to the atmosphere.



The Propulsion Wind Tunnel Facility (PWT) includes one supersonic and three transonic tunnels. In the photo is the main compressor of the 16-foot supersonic tunnel.

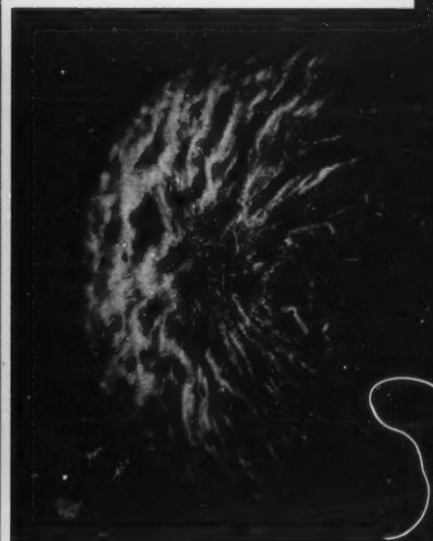




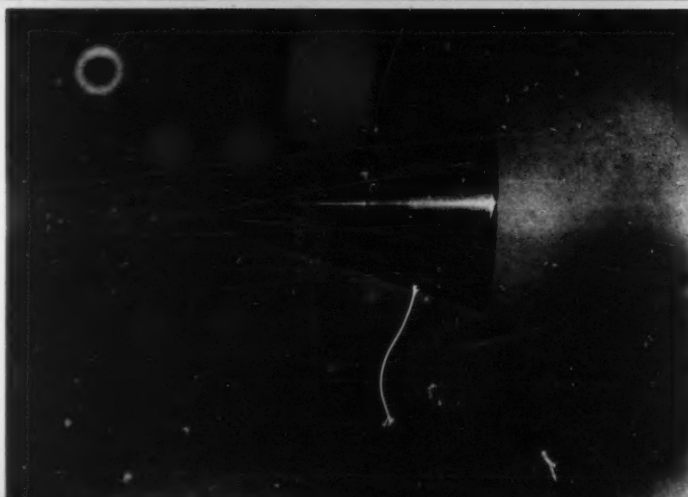
Part of the Von Karman Gas Dynamics Facility (VKF), this is one of four high vacuum space chambers in which full-scale spacecraft can be subjected to launch pressures, vibration, space vacuum, radiation and altitude conditions up to 1,000 miles.



The VKF's 40-inch variable density supersonic tunnel can simulate speeds from Mach 1.5 to Mach 6; airflow velocity is controlled by use of 80 electrically-driven jacks to vary the contour of the two flexible steel plates pictured.



Ultra-high-speed cameras spaced along the VKF's 1,000-foot ballistic range provide stop-action photography while a model is traveling at speeds up to 20,000 miles per hour. In this view, a missile nose cone model flying at 12,300 miles per hour is "frozen," enabling observation of surface details and shock waves.



This color-enhanced laser photograph pictures an in-flight evaluation of a transpiration-cooled nosetip technique, in which thermal protection of a missile nosetip is provided by a cooling layer of water. Purpose of this test, conducted in the VKF's hyperballistic range, was to determine how much coolant is needed to keep the nosetip from melting. The nosetip was flying at 16,000 feet per second when the photo was taken.

CAREERS IN AEROSPACE: A BROAD HORIZON

In response to requests from the aerospace educational community, Aerospace magazine presents this summary of career opportunities in the aerospace industry

Aerospace is the huge aircraft that can whisk 300 passengers across the United States in a few hours. It is launch vehicles and spacecraft that can put men and women into space and bring them back. It is satellites that study Earth's resources and weather, and bring distant events into your living room as they are happening. It is superior missiles, bombers, and fighter aircraft, and other weapon systems that the nation needs for its defense. It is business and personal aircraft that provide pleasure or quick, convenient travel for busy people. It is helicopters that can do anything from rescuing accident victims to serving offshore oil rigs.

And aerospace is much more. Technological advances in space have found everyday use in fields as diverse as medicine, agriculture, communications, meteorology, energy, building design and manufacturing. Aerospace has affected the development of products as ordinary as coke bottles, as invaluable as heart pace-makers and as critical as devices for early detection of radioactive leakage.

While aerospace literally took off from incredible advances in the science of aerodynamics, it has developed solid production roots in a manufacturing industry that provides jobs for well over a million Americans in research, develop-

ment and production of aircraft, missiles, spacecraft and associated equipment. Thousands of workers in other industries produce parts, machinery and equipment used in aerospace and thousands of federal employees work in aerospace-related jobs because of the government's role as a prime purchaser of industry products.

Industry sales are at near-record levels and a booming future is predicted as defense expenditures continue to rise and airlines modernize their fleets. Because of the U.S. aerospace industry's technology lead and quality products and services, foreign sales remain a major pillar of the industry; a high percentage of aerospace workers owe their jobs to sales abroad.

THE INDUSTRY'S PRODUCTS

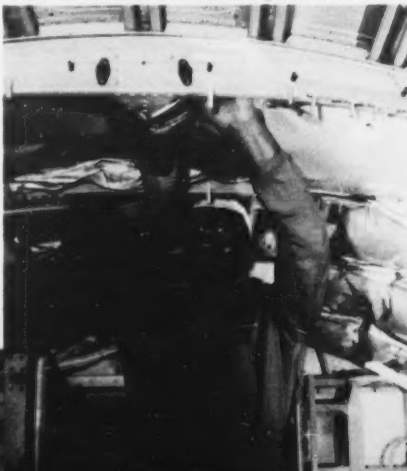
Aerospace firms produce primarily air-

craft, missiles, spacecraft and space launch vehicles, all of which have the same basic components: an airframe, an engine—either piston, jet or rocket powered—and a guidance and control system.

Industry customers include the U.S. government, foreign governments, commercial airlines, and private firms and individuals. In the U.S., aerospace product and service sales to the government generally exceed non-government or commercial sales.

Aircraft—including transports, bombers and fighters for military use, and aircraft for commercial passengers, freight airlines and private use—represent the largest component of industry sales. Missiles are purchased by the government for military use. Spacecraft are used by the National Aeronautics and Space Administration (NASA) and the Department of Defense to explore space, to examine the Earth's surface and atmosphere, and for practical applications, such as communications. Sometimes NASA places communications, navigational or research satellites into orbit for private companies or for other countries.

When a major aerospace firm contracts with government or private business to produce an aerospace vehicle, the firm



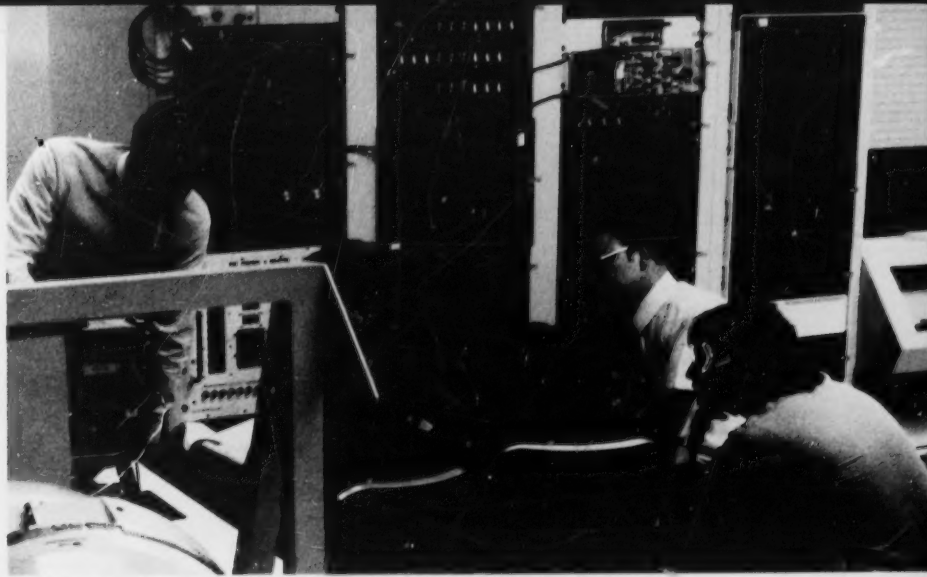


Technicians work to apply final touches to the Shuttle Orbiter *Atlantis*, to be launched by NASA in 1985.

is responsible for managing and coordinating the entire project, including design and manufacture. Although the prime aerospace manufacturers make many components of a vehicle and do final assembly themselves, thousands of subcontractor firms provide parts and supplies—from bearings, fasteners and nuts and bolts to specialized metal parts and seats—and other equipment required for the “fitting out” of aircraft. Subcontractors also produce the propulsion systems, landing gear, electronics and hydraulic equipment—sometimes entire subassemblies of an aerospace vehicle. Still other firms may supply parts of subassemblies. It is an interrelated process, involving thousands of U.S. companies and extensive resources.

OCCUPATIONS IN AEROSPACE

Aerospace involves extremely complex technology, so firms in the industry need workers with many different types of skills. Most jobs in aerospace manufacturing are either professional and technical occupations, management and administrative occupations, or plant occupations.



Engineers confer on plans for developing an aircraft-related system.

Professional and Technical Occupations

Many types of engineers, scientists and technicians work together developing designs for aircraft, missiles and spacecraft. Aerospace, chemical, electrical, electronics, industrial and mechanical engineers are among the larger groups of engineering specialists. Aerospace engineers work mainly in the aircraft and parts industry, often specializing in such areas as structural design, engines, navigational guidance and control, instrumentation and communication, or production methods. Scientists include physicists, mathematicians, chemists, metallurgists and astronomers, among others. Both engineers and scientists work in a wide range of applied fields such as materials and structures, energy and power systems, and space sciences.

Drafters assist engineers and scientists. They prepare detailed drawings based on rough sketches, specifications and calculations made by engineers and scientists. Final drawings include a detailed view of the vehicle from all sides, specifications for materials, and other necessary information.

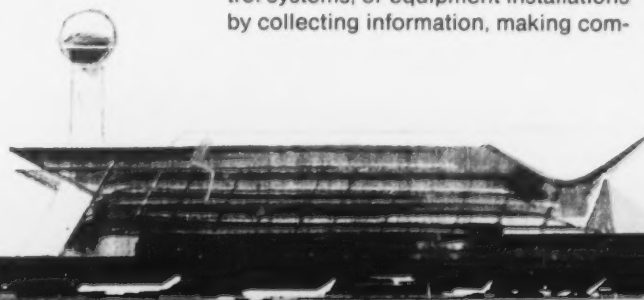
Technicians aid in preparing designs, layouts and models of structures, control systems, or equipment installations by collecting information, making com-

putations, and performing laboratory tests. They may prepare specifications for materials or supervise production workers to be sure plans are followed. Some technicians serve as manufacturers' field service representatives—the link between the company and its customers.

Also assisting scientists and engineers are production planners who develop layout of machinery, movement of materials and the sequence of operation for manufacturing processes, and technical illustrators who help prepare manuals and technical literature describing operation and maintenance of products.

Management and Related Occupations

Managerial and administrative jobs in aerospace are comparable to similar jobs in other industries except these positions in aerospace are often filled by people with backgrounds in engineering or science. Such positions include executives responsible for direction and supervision of research, development and production and officials in sales, purchasing, accounting, industrial relations, and public relations. Many thousands of clerks, secretaries, computer personnel and other office workers are employed in the administrative portion of the aerospace industry.





Lab technicians prepare a navigation satellite for launch into space.



Overview of a plant where assembly of aircraft, missiles and rockets takes place.

Plant Occupations

About half of all workers in aerospace have plant or production-related jobs. Plant occupations include: sheet-metal work; machining; tool fabrication; other metal processing; assembly and installation; inspecting and testing; flight check-out; and materials handling, maintenance and custodial.

TRAINING AND QUALIFICATIONS

A college degree in engineering or one of the sciences is usually the minimum requirement for an entry position in aerospace as an engineer or scientist. Technicians sometimes can achieve these positions without a degree, but only after years of experience and some formal training. An undergraduate preparing for a career as an aerospace engineer or scientist should get a solid background in mathematics and physics. More specialized fields of the industry require graduate school education or on-the-job training.

Technicians generally attend a technical institute or junior college or receive training in the armed forces. Highly skilled plant workers may advance to technician levels by taking courses in areas such as metallurgy, electronics or drafting.

Entry-level plant occupations generally do not require a degree, although a high school diploma and vocational courses in electronics or mechanics are preferred—especially for more skilled, higher paying jobs. Inexperienced workers generally start in semiskilled positions and learn on the job or in courses provided by employers. With experience, they can move into more highly skilled positions.

Apprenticeship programs, lasting about four years, are available for craft occupations such as machinists, tool-and-die makers, sheet-metal workers, aircraft mechanics and electricians. The programs vary from three to five years in length, during which the apprentice handles work of progressively increasing difficulty. Because of rapid changes in technology, firms also supplement day-to-day experience through short-term training programs.

EMPLOYMENT

The aerospace industry employs about 1,200,000 workers. About half of those work in production, while nearly one-fourth find employment as scientists, engineers and technicians. Aircraft manufacture generally accounts for more than 50 percent of industry employment and missiles and spacecraft manufacture for more than 20 percent. Another 25 percent of workers are involved in manufacture of other products such as avionics. Production workers are the largest group of employees in every segment of the industry.

Aerospace jobs exist in almost every state, but the highest concentration of employees is in the Pacific states, especially California and Washington. The New England region ranks second. New York, Texas, Missouri and Kansas all have large numbers of aerospace jobs.

OUTLOOK

Total aerospace employment is expected to remain strong through 1990. Thousands of jobs should open each year because of the expected increases in defense spending, anticipated increases in research and development funding,

demand for commercial transport aircraft, and the need to replace workers who die, retire or transfer to other industries. There will be many opportunities for scientists, engineers and skilled plant personnel.

THE AEROSPACE CHALLENGE

It is the emphasis on research and development that makes the aerospace industry an important source of jobs for technical personnel. Almost 20 percent of all engineers and scientists engaged in R & D in U.S. industries are employed by the aerospace industry.

The pace of innovation and change in aerospace is so great that much equipment becomes obsolete while still in an experimental stage or shortly after being put into production. This means that a continuation and expansion of the United States worldwide superiority in aerospace depends upon important research breakthroughs and their early application to technology and productivity. It means also that the aerospace industry relies heavily on those with maximum scientific, engineering or technical skills.

Ahead in the industry are aircraft that feature aerodynamically improved wings, advanced power plants, new flight control systems, and a host of improvements not yet on the drawing board. In space, the possibility of producing such items as advanced pharmaceuticals, superior crystals for electronics, and stronger, lighter, more temperature-resistant metal alloys presents new opportunities. The aerospace future is exciting. It is also demanding of highly-educated, motivated people to carry on the tradition of innovative technological advances on which aerospace progress depends.

FOR MORE INFORMATION

CONTACT . . .

National Aeronautics and Space Administration, LFC
400 Maryland Avenue, S.W., Washington, D.C. 20546 (202) 453-8393

Federal Aviation Administration
Public Inquiry Section (APA-400)
Office of Public Affairs
800 Independence Avenue, S.W., Washington, D.C. 20591 (202) 426-8058

American Institute of Aeronautics & Astronautics
Student Programs
1633 Broadway, New York, New York 10019 (212) 408-9727

National Society of Professional Engineers
2029 K Street, N.W., Washington, D.C. 20006 (202) 463-2300

American Society of Mechanical Engineers
345 E. 47th Street, New York, New York 10017 (212) 644-7722

University Aviation Association
P.O. Box 2321, Auburn, Alabama 36831 (205) 826-4597

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Information on careers, outlooks and requirements specifically tailored to requests of students and teachers

"Aviation Career Series," brochures on training, duties and job outlook in aerospace industry

"Within Your Lifetime—Careers in Aerospace," lists disciplines, requirements (\$1/copy)

Brochures on engineering careers in aerospace

"A Career for the future,"—booklet on careers in mechanical engineering

Comprehensive book of colleges and universities with aviation programs (\$9.95/copy)

SOME WAYS TO GET INVOLVED NOW

Directory of Science Training Programs, Science Service, Inc.
1719 N Street, N.W., Washington, D.C. 20036

"Exploring: The Young Adult Division of the Boy Scouts of America"
(Write to the Local Boy Scouts of America Council in your area)

NSTA-NASA Space Shuttle Student Involvement Program
National Science Teachers Association
1742 Connecticut Avenue, N.W., Washington, D.C. 20009

Ask your teachers and guidance counselors about other programs and internships they know about

Lists institutions conducting science training programs for high-ability junior and senior high school students

Age 14-20 men and women join aviation posts organized by local industry or business to learn about careers in aviation

National contest for 9-12 graders to develop experiments for Shuttle flight; winning proposals are considered for flight on Shuttle mission

ADDITIONAL RESOURCES

(Available at most libraries)

REFERENCE BOOKS

Occupational Outlook Handbook

Annual Publication of the U.S. Department of Labor

U.S. Industrial Outlook for 200 Industries with Projections for 1984

Publication of the U.S. Department of Commerce

Barron's Profiles of American Universities

Barron's Educational Series

MAGAZINES

AIAA Student Journal, American Institute of Aeronautics and Astronautics,
1633 Broadway, New York, New York 10019.

Aviation Space, Aerospace Education Association, 1910 Association Drive,
Reston, Virginia 22091.

Aviation Week & Space Technology, McGraw-Hill Publication, 1221 Avenue
of the Americas, New York, New York 10020.

Air Force Magazine, Air Force Association, 1501 Lee Highway, Arlington,
Virginia 22209-1198.



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AEROSPACE INDUSTRIES ASSOCIATION

1725 De Sales St., N.W., Washington, D.C. 20036

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OFFICIAL PUBLICATION OF THE AEROSPACE INDUSTRIES ASSOCIATION • WINTER 1985

AEROSPACE
REVIEW
AND
FORECAST
1984/85



Notable views of notable people on aerospace matters...

aerospace perspectives

Thomas G. Pownall, Chairman, Marietta Corporation, in a speech to the Washington (D.C.) Board of Trade:

"America remains the world's economic giant—the leading producer of goods and services, the most productive of nations in our factories and on our farms, the Number One exporter to the world, the Number One importer from the world, the technological pacesetter in most of the areas that will drive tomorrow, with industrial and government research and development programs at the forefront in virtually every key discipline. One quarter of all goods and services produced on the face of the Earth is produced in the United States. Our Gross National Product roughly equals the European Economic Community and Japan combined . . .

"Some observers have concluded that we are approaching the end of the long-playing American economic miracle, that we are likely to experience a low-growth, more limited, less competitive economy in the future. On the basis of the full body of evidence, I cannot agree. I do not see this highly talented and educated nation, bursting with energy and confident of its soaring capabilities, sinking into decline.

"What I do see emerging is an increasingly interdependent world here and overseas, served and linked and powered by 21st century technologies developed here and overseas, in which our economies interact more and more to the benefit of all nations. Trade, technology, international investment and finance, and economic development are propelling us toward a "One World" even more encompassing than a former businessman named Wendell Willkie foresaw back in the 1940s. In the political arena, obviously, the One World that Willkie suggested at the height of World War II is far from reality. But the interaction among economies, which he considered the other side of the coin, is a growing reality central to the economic future both here and abroad."

William H. Taft IV, Deputy Secretary of Defense, in an address to the National Security Industrial Association in Arlington, Virginia:

"It has become popular in some circles to proclaim the death of American ingenuity—but I don't believe it for a minute. What I do believe is that we sometimes stifle that ingenuity. When cartloads of military standards and specifications are applied *prematurely*, before we have learned what special problems or opportunities may arise during development—or *rigidly*, without tailoring to fit the particular program—or even *inadvertently*, through automatic reference to several subtiers of specification, we incur unnecessary costs . . .

"This is why it is so vital that reducing overspecification be a top-level management priority, both in the Department of Defense and in industry. Our people need to know that they will be rewarded for coming up with inventive ways to improve productivity and meet mission requirements at lower cost; indeed, they need to know that tailoring specifications and standards is a crucial *requirement* of their jobs . . .

"The Department of Defense (has been engaged) in a comprehensive attack on the problem of 'untimely, untailored and accidentally-referenced applications of specifications

and standards.' We are already seeing some important results. I am pleased to say we have had first rate cooperation from industry on this initiative . . .

"Allowing industry to have a greater role in identifying the most cost-effective application of specifications and standards is one important step toward improved defense productivity. But we must go further. We must recognize that the defense industry has not escaped the productivity and quality problems that plagued all American industry during the 1970s . . .

"As a partner in the drive to restore defense productivity, DoD is seeking to help industry acquire the tools needed to improve productivity and quality . . . During the coming year we hope to focus on ways that DoD and industry together can motivate and train both management and employees to give priority to quality . . .

"The aim of our productivity initiatives is to give industry the opportunity, the incentive and the tools to produce higher quality products at lower cost. We want to give (industry) more responsibility; we want (industry) to tell us *how* we can achieve what we need. We want to tap the ingenuity and experience of the world's most resourceful and technically capable workforce."

Caspar W. Weinberger, Secretary of Defense, speaking to the National Press Club, Washington, D.C.:

"I believe the postwar period has taught us several lessons, and from them I have developed six major tests to be applied when we are weighing the use of U.S. combat forces abroad. . . .

"First, the United States should not commit forces to combat overseas unless the particular engagement or occasion is deemed vital to our national interest or that of our allies. That emphatically does not mean that we should declare beforehand, as we did in Korea in 1950, that a particular area is outside our strategic perimeter.

"Second, if we decide it is necessary to put combat troops into a given situation, we should do so wholeheartedly and with the clear intention of winning . . .

"Third, if we do decide to commit forces to combat overseas, we should have clearly defined political and military objectives, and we should know precisely how our forces can accomplish those clearly defined objectives . . .

"Fourth, the relationship between our objectives and the forces we have committed—their size, composition and disposition—must be continually reassessed and adjusted if necessary . . .

"Fifth, before the U.S. commits combat forces abroad, there must be some reasonable assurance we will have the support of the American people and their elected representatives in Congress . . .

"Sixth, the commitment of U.S. forces to combat should be a last resort . . .

"The point we must all keep uppermost in our minds is that if we ever decide to commit forces to combat, we must support those forces to the fullest extent of our national will for as long as it takes to win."

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DIRECTOR
OF PUBLIC RELATIONS • David O. Schillerstrom

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EDITOR • John F. Loosbrock

ASSOCIATE EDITORS • James J. Haggerty

Ellen Kelly

Jean Ross Howard

ART DIRECTOR • James J. Fisher

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The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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A LOOK AHEAD

BY KARL G. HARR, JR.

President, Aerospace Industries Association

If we use inflation-adjusted sales volume as a yardstick of aerospace industry activity, 1984 was among the best years in the industry's history. In constant dollar terms, it trailed only the peak years 1967-68 when the industry was simultaneously engaged in military production for the Vietnam war and strategic missile programs, large-scale manufacture of commercial transports and fabrication of space equipment for the Apollo lunar landing program.

The high 1984 sales volume was achieved despite the fact that commercial transport sales dipped to the lowest level since 1978. Aerospace Industries Association feels, however, that the decline has bottomed and we look for a sharp rebound this year. That, along with projected increases in defense and space sales, should make 1985 the industry's new all-time record year.

Looking farther down the road, we see continuing high levels of aerospace activity in the coming decade. The world's airlines, although not yet robust, are regaining financial health and are already resuming their deferred reequipment programs. The driving forces are the need to replace older aircraft and, most importantly, to realize the significant operating economies offered by new, advanced technology transports. Forecasts show a very large market for jetliners; even the most conservative estimate exceeds the total of all transports delivered over the past 20 years. If market projections hold up, and if U.S. manufacturers can retain something close to their traditional market share in the face of growing competition, commercial transport production will increase to what could become the highest level ever.

With regard to space business, the most rapidly expanding area of the industry's workload in recent years, Administration plans coupled with indicated growth in commercial space operations suggest substantially higher levels of industry activity in coming years.

The defense business picture is somewhat uncertain. There is considerable evidence that the Administration's defense buildup may be compromised to a degree in view of the great concern about the national deficit. But pre-election polls and the outcome of the election have made it clear that a majority of the American people back President Reagan's security policies. In Congressional deliberations, no one is talking seriously of reducing defense outlays below current levels; the debate centers on whether or how much the defense budget should be increased. Thus, we anticipate moderate increases in defense spending—hence industry activity—throughout the Reagan Administration.

In summary, the industry's business prospects for the next decade must be rated good to excellent, because we see activity gains in two major areas of workload where we are already strong—defense and space—and, in the one area where business has been depressed in recent years—commercial transport manufacture—we look for an upswing beginning this year.

AEROSPACE HIGHLIGHTS 1984

By JAMES J. HAGGERTY

DEFENSE

In September, House and Senate conferees approved production of 21 additional Peacekeeper (MX) intercontinental missiles—on top of 21 already in production—but froze funding for the new weapons until each chamber of Congress reapproves the program this year.

Meanwhile, the Peacekeeper flight test program continued with four successful flights in 1984 from Vandenberg Air Force Base, California. The last of the four, on October 1, was the sixth Peacekeeper test, including two in 1983; it was a realistic simulation of an operational mission covering a flight of more than 4,700 miles. In 1985, Peacekeeper was to begin a new phase of testing in which the missiles will be launched from Minuteman test silos at Vandenberg. The USAF plans a total of 20 test flights; initial operational capability was targeted for late 1986.

Major Peacekeeper contractors include Martin Marietta Aerospace (assembly and test); Rockwell Autonetics (guidance and computers); Northrop (inertial guidance system); Morton Thiokol (first stage); Aerojet-General (second stage); Hercules Incorporated (third stage); Rockwell Rocketdyne (fourth stage); Avco Corporation and General Electric Company (re-entry systems); Westinghouse (missile canister); Boeing (support equipment); TRW Inc. (engineering and technical support); and Honeywell Inc. (guidance and control elements).

Development continued on the Air Force's Small ICBM program with award of study contracts for propulsion and launch systems. Aerojet-General, Hercules, Morton Thiokol and United Technologies received contracts to study boost systems; Bell Aerospace, Boeing, General Dynamics and Martin Marietta won contracts for study of mobile launch systems. Full-scale development of the Small ICBM was planned for 1986, with flight testing to begin in 1988.

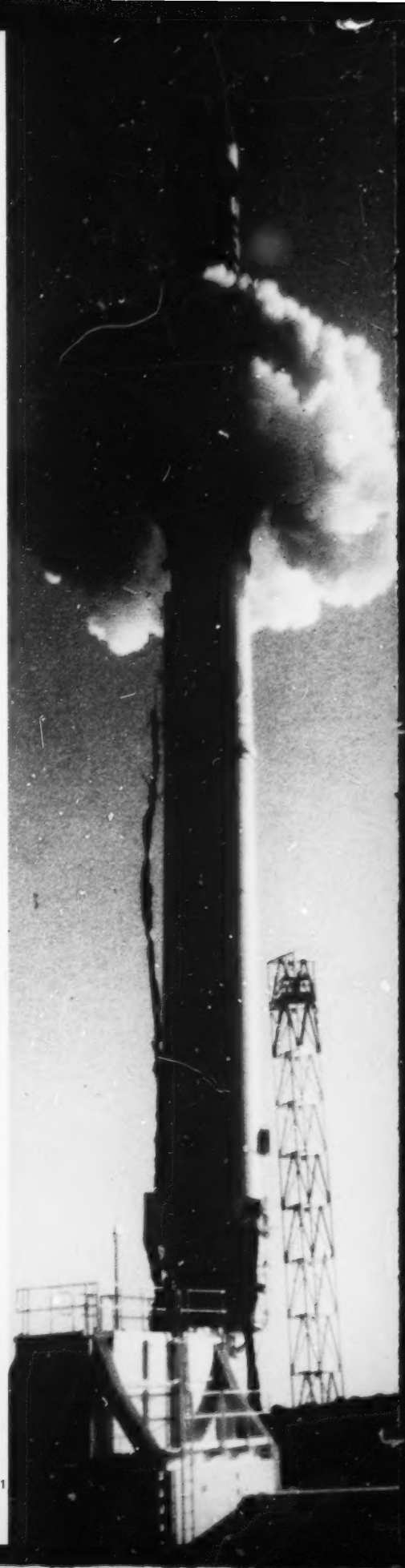
In April, the USAF formed a separate Strategic Defense Initiative (SDI) Organization to manage the antiballistic missile defense research program. Funded at \$1.5 billion for 1985, SDI is one of the

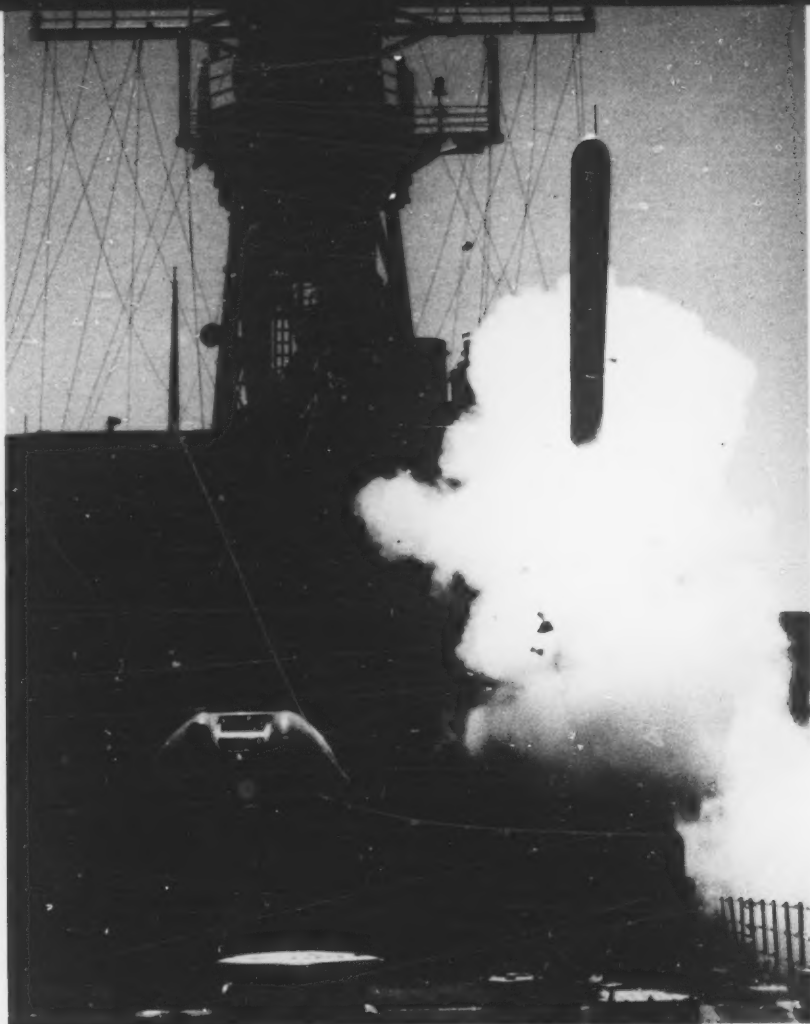
largest Department of Defense R&D programs; it is a study and technology development effort intended to explore a variety of space-based, aircraft-based and ground-based missile defense possibilities toward eventual definition of an antiballistic missile defense system.

Engineering development of the Trident II submarine-launched ballistic missile continued in 1984. The Navy awarded contracts for development and production of the first 52 missiles to Lockheed Missiles & Space Company (prime contractor), Westinghouse Electric Corporation (launcher subsystem) and General Electric Company (fire control system). Deployment of Trident II is planned for 1989. In 1984, the Lockheed-built Trident I was in operational status aboard Trident-class nuclear submarines.

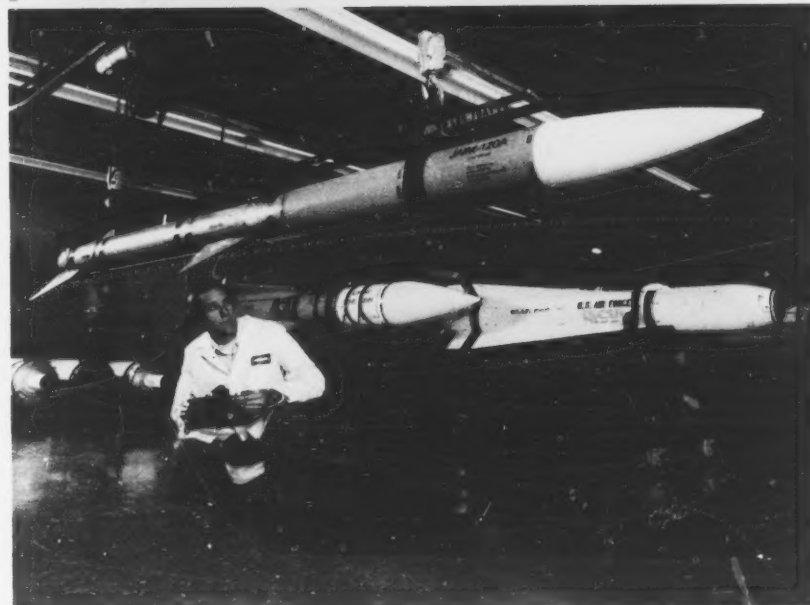
Deployment in Europe of the Army/Martin Marietta Pershing 2 ballistic missile continued in 1984, as did developmental flight testing. At Cape Canaveral, Florida, the Army Missile Command conducted four environmental test launches of Pershing 2 in which the missile was alternately exposed to unusual pre-launch levels of heat and cold.

The Tomahawk cruise missile was in development and production in several different versions produced by prime contractor General Dynamics and second source associate contractor McDonnell Douglas; the latter company delivered its first production missiles. Deployment of the Tomahawk GLCM (Ground Launched Cruise Missile) in NATO countries continued in 1984. Operational tests of the SLCM (Sea Launched Cruise Missile) were completed and deployment of the weapons on submarines was initiated. The TLAM-N (Tomahawk Land Attack Missile-Nuclear) was declared operational in June but not officially deployed at sea due to a Congressional moratorium on deployment. The conventional-warheaded TLAM-C was flight tested with live warheads and in "pop up" maneuvers involving vertical terminal dives for more accurate attack, tests not previously accomplished. General Dynamics was also working under





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1. The USAF conducted four successful tests of the four-stage Peacekeeper intercontinental missile in 1984; 14 additional tests were planned.
2. The Tomahawk cruise missile was in development and production in several versions. The version pictured is the Navy's Sea Launched Cruise Missile, shown being fired from a launcher on the deck of a destroyer.
3. In December, the first production model of the AMRAAM (Advanced Medium Range Air-to-Air Missile) was test flown.
4. The RAM (Rolling Airframe Missile), a fast-reaction Navy ship-board defense weapon, completed a series of development tests.

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Air Force contract on an Advanced Cruise Missile intended as a complementary system to the Boeing-built ALCM (Air Launched Cruise Missile). Production of the latter weapon was completed and the USAF announced plans for upgrading the 1,700 ALCM's with retrofits.

In other 1984 missile developments,

- The Air Force conducted the first two of a planned 12 flight tests of the experimental Miniature Homing Vehicle antisatellite system, one in January and one in November. The USAF withheld details. LTV Aerospace and Defense Company is ASAT contractor.

- The RAM (Rolling Airframe Missile), a joint U.S.-West Germany shipboard defense system, completed a series of development tests and was being readied for operational tests at sea. General Dynamics is the U.S. contractor.

- Testing continued on the Hughes-built AMRAAM (Advanced Medium Range Air-to-Air Missile) and, in December, the first production model of the missile was test flown at White Sands Missile Range, New Mexico.

- In January and November, the Army conducted successful tests of the LTV Aerospace SHRIT (Small Homing Rocket Interceptor Technology) missile, simulating trajectories to intercept re-entry vehicles.

The year's highlight in military aircraft development was the successful initial flight—in October—of the first production model B-1B, built by Rockwell International for the Air Force. The B-1B was scheduled for initial operational capability late in 1986. Among other military aircraft highlights:

- In October, the Air Force awarded a contract to McDonnell Douglas for development of an advanced technology F-15 STOL (Short Takeoff and Landing) demonstrator. First flight was targeted for 1988.

- In July, General Dynamics started deliveries of the F-16C, an improved version of the F-16A USAF fighter. In September, the company received a contract to modify an airplane for feasibility flight tests of a reconnaissance version of the F-16.



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- In August, the Navy began testing of a McDonnell Douglas F/A-18 modified for use as a reconnaissance aircraft. The fighter version of the F/A-18 passed its first tests with an operating squadron aboard an aircraft carrier.

- Development of the USAF/McDonnell Douglas C-17 military transport progressed with completion of mockup-based tests involving loading and unloading of heavy equipment, including trucks, tanks and helicopters. A decision as to whether the Department of Defense would proceed with full-scale development of the C-17 was expected early in 1985.

- The X-29A research airplane, which incorporates a foreswept wing and a number of other advanced technologies, made its first flight in December.

- In March, Gates Learjet Corporation rolled out the first of 80 C-21A operational support aircraft being built for the Air Force. The C-21A is a military version of the Learjet 35A business/utility transport.



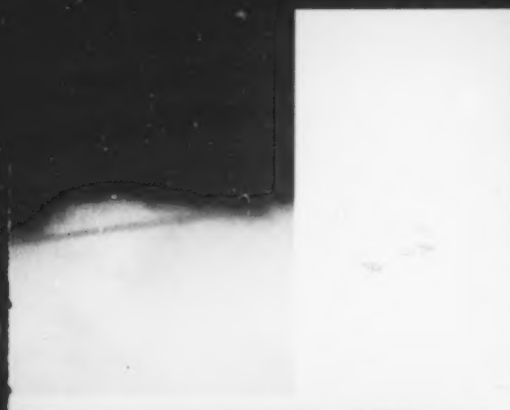
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- The Navy initiated development of an improved Grumman F-14D with an advanced engine, new radar and all-digital avionics.

- In November, Northrop Corporation started construction of another F-20 tactical fighter demonstrator to join the two already in the flight test program.

- At year-end, Boeing was completing work on the first model of a new EC-18B ARIA (Advanced Range Instrumented Aircraft), an airborne tracking station for support of missile and space tests. The EC-18B, a modified Boeing 707, is a stretched version of the existing ARIA.

- In August, the Army/Hughes Helicopters AH-64 attack helicopter made first firings of laser-guided Hellfire missiles using a production model target acquisition system developed by Martin Marietta Orlando Aerospace. Deliveries of the AH-64 reached 16; Hughes Helicopters had orders for an additional 144.

- In July, Bell Helicopter Textron delivered the first five prototype OH-58D

helicopters in the Army Helicopter Improvement Program. The upgraded AHIP helicopter incorporates new sensors, displays, controls and dynamic components. Bell was in production on 16 OH-58D helicopters; the Army plans a large-scale, seven-year procurement program.

- First fleet shipboard operations of the Navy-Sikorsky/IBM SH-60B LAMPS (Light Airborne Multipurpose System) Mark III helicopters were conducted in the summer.

- Sikorsky's HH-60D USAF search and rescue helicopter made its first flight in February. Following completion of a series of tests, the prototype was ferried to IBM for installation of avionics equipment and a series of avionics test flights.

- In engineering development status was the Joint Services Vertical Lift Aircraft (JVX), a Navy-managed program for a tilt-rotor transport/utility aircraft intended for service in the 1990s. Contractors are Bell Helicopter Textron, which built the XV-15 prototype from which the JVX derives, and Boeing Vertol Company.

5. The first production model of the USAF B1B bomber made its initial flight in October.

6. In October, the USAF started development of a STOL version of the F-15 fighter.

7. Deliveries of the F-16C, an improved version of the Air Force fighter, began in July and development of a reconnaissance version was initiated.

8. Gates Learjet delivered the first of 80 C-21A operational support aircraft to the Air Force in March.

9. The X-29 A research airplane, featuring a fore-swept wing, flew for the first time in December.

10. Operational testing of the Army's AH-64 attack helicopter included firings of the Hellfire antitank missile.

SPACE

For the National Aeronautics and Space Administration, 1984 was highlighted by five successful Space Shuttle missions, including the first retrievals of orbiting satellites.

The Shuttle year began with flight 41-B in February, primary objective of which was to check out the Manned Maneuvering Unit (MMU), built by Martin Marietta Aerospace, a backpack propulsion/ guidance system that enables astronauts to operate in space outside the Shuttle Orbiter. Astronauts Bruce McCandless and Robert L. Stewart, with MMUs strapped over extravehicular space suits developed by United Technologies' Hamilton Standard division, became the first "human satellites;" untethered to the Orbiter *Challenger*, they flew as far as 300 feet from the Orbiter.

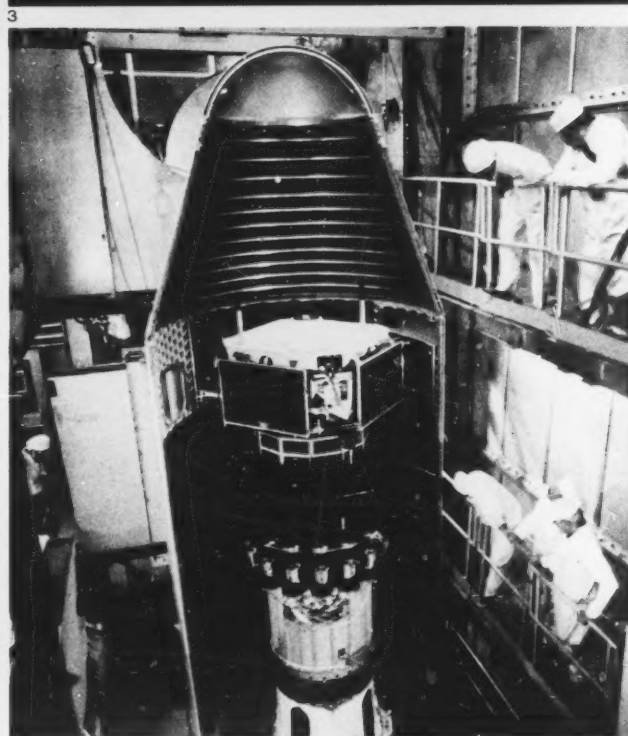
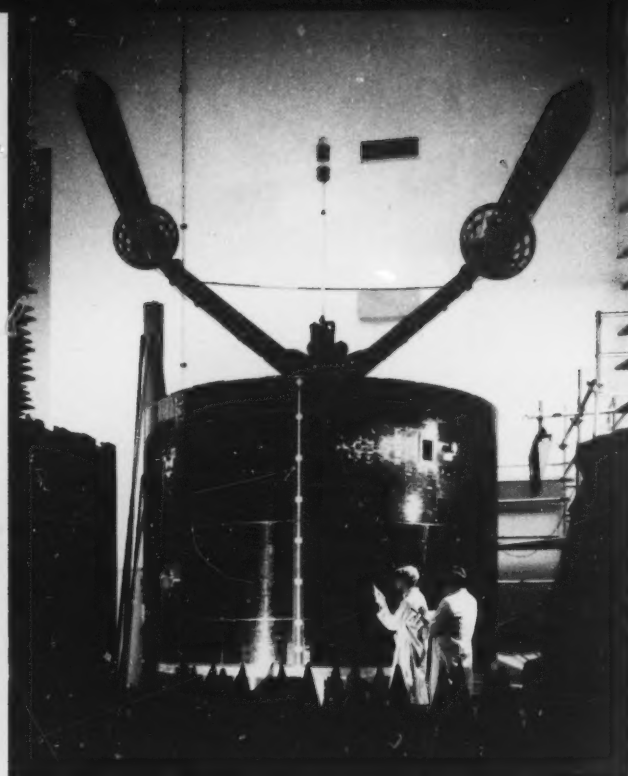
The success of 41-B, the 10th Shuttle flight, set the stage for 41-C in April. One of the most spectacular Shuttle missions, 41-C involved recapture and repair of the Solar Maximum Mission spacecraft; launched in 1980 for continuous long-term observation of solar flares, Solar Max had malfunctioned in 1981. On 41-C, astronaut George Nelson flew his MMU to a rendezvous with Solar Max, stabilized it, then maneuvered it back to the Shuttle Orbiter. He and James van Hoften stowed the satellite in the cargo bay and replaced the malfunctioning module with a new one. Solar Max was then redeployed in orbit to continue its solar observations, a dramatic demonstration of Shuttle utility.

In August, NASA launched the Orbiter *Discovery* on mission 41-D with the heaviest payload thus far carried by the Shuttle, including more than 30,000 pounds of commercial communications satellites. The crew successfully deployed the three Hughes-built satellites: Leasat, a military communications system; Satellite Business Systems' SBS-4; and AT&T's Telstar 3-C. The launch of SBS-4 marked the return to Shuttle service of the McDonnell Douglas/Thiokol PAM (Payload Assist Module) upper stage booster after correction of problems experienced earlier in the year. Mission 41-D carried the first commercial astronaut, McDonnell Douglas Astronautics' Charles Walker, who operated the company's electrophoresis system for processing pharmaceuticals in space. The flight also featured the first space test of a large, lightweight, foldable solar array built by Lockheed Missiles & Space Company; the 105-foot-long structure was repeatedly deployed and retracted, demonstrating the practicability of using king-size solar wings as power sources for extended Shuttle missions, for the space

1. On an April Shuttle flight, astronaut George Nelson is flying a Manned Maneuvering Unit to retrieve the Solar Maximum Mission spacecraft.
2. November's Shuttle spectacular: astronaut Joe Allen maneuvers the previously stranded Palapa-B2 commercial communications satellite into the Orbiter's cargo bay; the Westar 6 comsat was retrieved on the same mission.
3. Two Leasat defense comsats were Shuttle-launched, one in August, one in November.
4. Three AMPTE scientific satellites are being prepared for August launch aboard a single Delta booster.
5. Shown being readied for shipment is a Spacenet commercial communications satellite, one of four in the GTE Spacenet network. The first two were launched in May and November.



2



station and for large unmanned orbiting platforms.

Launched in October, flight 41-G included tests of the advanced SIR-B Shuttle Imaging Radar, deployment of the Earth Radiation Budget Satellite, tests of Shuttle-based hardware for refueling satellites in orbit, and mapping Earth's surface with a new, high resolution Large Format Camera.

Mission 51-A in November was highlighted by retrieval and return to Earth of Palapa-B2 and Westar 6, Hughes-built communications satellites that had been sent into useless orbits on Flight 41-B. Astronauts Joseph P. Allen and Dale Gardner recaptured and stowed the satellites for return to Earth and refurbishment for reuse. Prior to the retrieval operation, the crew successfully launched two other commercial communications satellites, the SPAR-built Anik 2 and a second Hughes Leasat. Mission 51-A closed out a Shuttle year that demonstrated conclusively the versatility and operational effectiveness of the Space Shuttle system. Rockwell International is Shuttle prime contractor.

In addition to the Shuttle-launched payloads, other civil satellites delivered to orbit during the year included:

- Landsat 5, fifth and most advanced of the Earth resources observation satellites built by General Electric Company's Space Division. NASA launched it in March with a McDonnell Douglas Delta vehicle.

- A team of three AMPTE (Active Magnetospheric Trace Particles Explorers), one each supplied by the U.S., West Germany and the United Kingdom. Designed to study how plasma—electrified gas—is transported through the magnetosphere, the satellites were sent into orbit aboard a single NASA Delta in August.

- The RCA-built Spacenet 1 and 2, first two of four satellites in a commercial communication network operated by GTE Spacenet Corporation. They were launched by the European Ariane in May and November.

- A Hughes Galaxy business communications satellite, operated by Hughes Communications, Inc., launched in September by a NASA Delta.

- The NOAA-9 meteorological satellite, another in the network of environmental spacecraft operated by the National Oceanic and Atmospheric Administration. Built by RCA Astro-Electronics, it was launched in December by a General Dynamics Atlas vehicle.

In non-launch NASA activity, the Voyager 2 interplanetary spacecraft continued to function well on its journey through the solar system to an encounter next year with the planet Uranus. Orbiting the Sun at a distance of some two billion miles, Uranus has never been visited by spacecraft and has been ob-



6. Late in the year, NASA started evaluation contractor proposals for space station design.
7. The artist's concept shows the Galileo Jupiter-exploration spacecraft and its Centaur booster after release from the Shuttle Orbiter. Galileo will be launched next year.
8. In development for service in the 1990s is a major astronomical observatory, the Advanced X-ray Astrophysics Facility.

served only dimly by Earth telescopes.

Another NASA spacecraft, the International Cometary Explorer, was en route to an encounter—in September of this year—with the Comet Giacobini-Zinner; it will be the first close encounter with a comet. NASA was also preparing for observation of Comet Halley beginning early next year. NASA will have no close encounter spacecraft—as will the Soviet Union, Japan and the United Kingdom—but it will make extensive observations from a distance with its Hughes-built Pioneer Venus Orbiter, Solar Max, the International Ultraviolet Explorer and a new Shuttle-based three-telescope observatory called Astro.

At year-end, NASA was evaluating bids from more than 100 companies and research organizations and preparing to award a series of contracts for definition of various aspects of the space station

and associated vehicles, such as the Orbital Transfer Vehicle and Orbital Maneuvering Vehicle. The contracts were to cover 18 months of study and definition work, after which NASA will select contractor teams for hardware development of several "packages"—space station structures, modules, power and control systems, on-board equipment and automated free-flying platforms that will complement space station operations.

Among other major NASA development programs active in 1984 were:

- Galileo, a two-in-one spacecraft system—one element an orbiter, the other an atmospheric probe—for advanced exploration of Jupiter, set for launch in May of next year. In a late 1984 modification to the flight plan, NASA included an option to make the first close

fly-by of an asteroid en route to Jupiter; final decision on exercising the option will be made after launch. Jet Propulsion Laboratory is building the Galileo orbiter; Hughes Aircraft and General Electric are teaming on probe development.

- The Hubble Space Telescope, an orbiting observatory capable of expanding man's view of the cosmos 350 times in comparison with existing ground-based telescope systems. The observatory will be Shuttle-launched in 1986. Lockheed Missiles & Space Company is NASA's prime contractor for the spacecraft, Perkin-Elmer Corporation for the optical assembly.

- The Venus Radar Mapper, which will penetrate Venus' cloud cover to map in greater detail than was earlier accomplished 90 percent of the planet's surface. To be launched in 1988, it is being developed under Jet Propulsion Laboratory management by Martin Marietta Aerospace (spacecraft) and Hughes Aircraft (imaging radar).

- The Advanced X-ray Astrophysics Facility (AXAF), intended to observe x-ray sources in the universe 100 times weaker than those viewed by predecessor x-ray observatories. In 1984, TRW Inc. and Lockheed Missiles & Space Company were awarded system definition contracts for AXAF, which is targeted for orbital service in the early 1990s.

- The Gamma Ray Observatory, planned for launch in 1988 to study how gamma rays are produced and where they come from.

The military space program continued the rapid growth evidenced in recent years. Although military space details are classified for the most part, the Department of Defense generally was replacing existing communications, weather and intelligence-gathering satellites with more advanced systems, preparing for next year's introduction of the Space Shuttle to military operations from Vandenberg Air Force Base, California, and developing advanced capabilities in space weaponry, missile attack warning, communications security and spacecraft survivability. Among unclassified developments of 1983:

- The Department of Defense launched the ninth and 10th satellites in a Block I test series of the Navstar Global Positioning System for precise location of air, sea and land vehicles. Prime contractor Rockwell International was developing advanced operational versions to replace the test satellites beginning in 1986; target for operation of the complete 18-satellite network is 1988.

- In development by Lockheed Missiles & Space Company was Milstar, a highly survivable satellite that will operate in the extremely high frequency range and provide secure communications to Army, Navy, Marine Corps and Air Force strategic and tactical forces.



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CIVIL AVIATION

New records in passenger traffic, cargo traffic and operating profit, and the first net profit in several years, marked the improving traffic and financial performance of U.S. airlines in 1984. The Air Transport Association reported that the airlines transported about 340 million passengers, up from the previous record of 318 million set in 1983. Final air freight results for the year were expected to top 6.5 billion revenue ton miles of service; the previous high was six billion ton miles in 1983. The volume of mail moving by air was also up in both domestic and international service.

Operating profit was almost \$2 billion, surpassing the previous operating profit record of \$1.4 billion in 1978. When final results for the year are in, it is expected that the net profit will be between \$600 million and \$800 million. ATA credited

four major areas of favorable economic impact for the airlines' financial performance upturn: an improved economy, declining fuel prices, moderation in labor cost increases and less intensive price wars. These factors, ATA said, will constitute the major influences on the airlines' 1985 performance.

The value of commercial transport aircraft on order or option by U.S. carriers at year-end amounted to about \$30 billion, this included orders for 446 aircraft valued at \$16 billion and options for an additional 401 transports worth \$14 billion.

From the manufacturing standpoint, 1984 was a bad news/good new year. Sales of civil aircraft declined once more, as they had in the two previous years—this time by 23 percent. The good news was that the decline appeared to have

1. First of the new generation Boeing 737-300 transports was delivered in November.

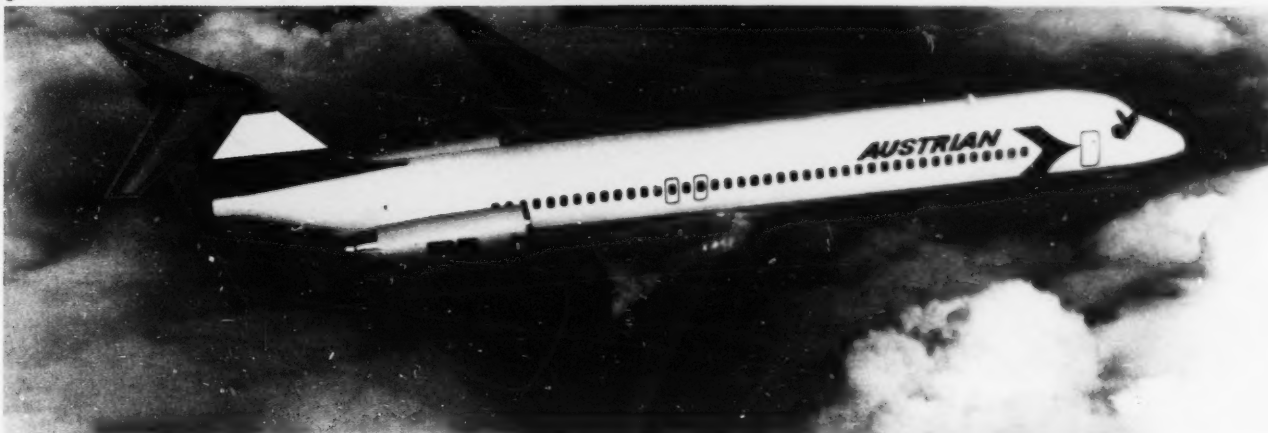
2. Also in November, Delta Air Lines took delivery of the first of 60 Pratt & Whitney-powered Boeing 757s.

bottomed and a production upswing was expected in 1985 and later years.

In the commercial transport manufacturing segment of the industry, sales amounted to \$5.7 billion, down from \$8 billion in 1983. The industry delivered 185 jetliners, which compares with 262 in the previous year. However, orders for new transports picked up sharply in 1984 and the backlog at year-end was the highest since 1980.



3



4

Transports in production included the Boeing 727, 737, 747, 757, and 767, and the McDonnell Douglas MD-80 series and DC-10. At the end of the year's third quarter, Boeing had orders on the books for 358 airplanes; the 737 led the list with 168. McDonnell Douglas had orders for 157 jetliners, all but five of them for the twinjet MD-80 and new variants of that model.

McDonnell Douglas launched a new member of the MD-80 series, the MD-87, a shortened 130-seat version (compared with 155 in the basic MD-80) powered by Pratt & Whitney JT8D-200 engines. Finnair and Austrian Airlines became the first carriers to order the MD-87, deliveries of which will start late in 1987. Another new model in production was the MD-83, also powered by the JT8D 200 Series engines. Scheduled for first deliveries this spring, the MD-83 has the standard fuselage length but increased takeoff weight.

In November, Boeing delivered the first of its new generation 737-300 jetliners, following nine months of certification flight testing. USAir, which had placed orders for 30 of the airplanes, became the first airline to take delivery. The 737-300 is powered by CFM56-3 engines, built by an international company composed of General Electric and the French SNECMA. Also in November, Boeing delivered to Delta Air Lines the first of the 757 family powered by Pratt & Whitney PW2037 engines; Delta had

60 of the 187-seat transports on order.

General aviation aircraft manufacturers delivered fewer aircraft than in 1983 but their dollar value was up by more than 15 percent, due largely to an increase in sales of higher-value business jets. General aviation sales totaled \$1.7 billion, compared with \$1.5 billion in 1983.

The rotary wing segment of the industry produced 418 helicopters valued at \$336 million, up from the previous year's 401 units worth \$269 million. Major commercial helicopter types in production included the Sikorsky S-76 and Bell Helicopter Textron Model 222 twin-turbine transports, the 44-passenger Boeing Vertol Model 234 and Bell's new Model 400 TwinRanger, a seven-seater with a four-bladed main rotor made of composite materials. A new manufacturing program in 1984 was production by Schweizer Aircraft Corporation of the Hughes 300C helicopter under a licensing agreement with Hughes Helicopters. The first Schweizer-built 300C was delivered in June and by year-end the company had delivered 13 of the helicopters.

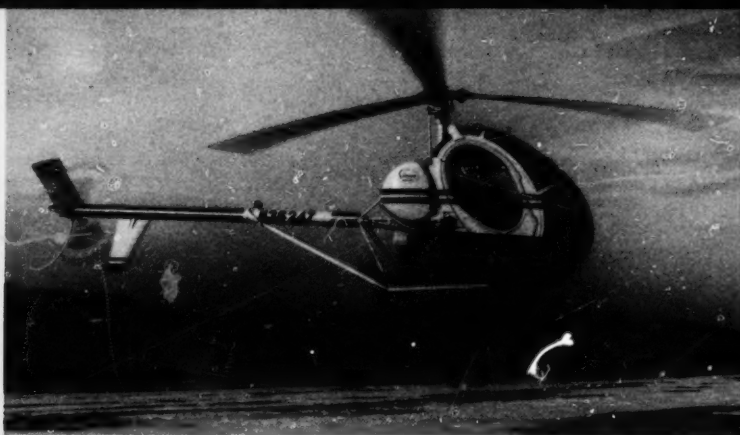
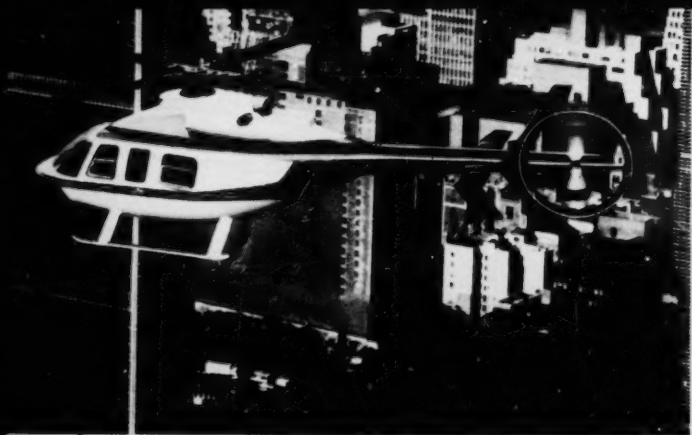
Sikorsky started deliveries on an order from the Peoples Republic of China for 24 S-70C civil versions of the Black Hawk military helicopter, marking the first sales of Sikorsky aircraft to mainland China.

Selected by Canada to develop a Canadian helicopter industry, Bell started construction on a new facility near Montreal and initiated labor hiring. The plant will be used for production of the Model 400.

In civil aviation research, NASA started a new phase of the Sikorsky-built Rotor Systems Research Aircraft (RSRA) program. The RSRA was flown as a fixed-wing airplane with its rotor removed, power supplied by jet engines normally used to test the aircraft as a compound (wing plus rotor) helicopter. These tests were aimed at determining the RSRA's handling qualities in the fixed-wing mode as a preliminary to a joint NASA/Defense Advanced Research Projects Agency X-wing program. One of the two RSRAs was converted to the X-wing configuration for flight testing; the X-wing features a rotor that can be stopped in flight to become, in effect, a fixed airfoil for greater speeds than can be attained with a rotor system.

NASA also continued flight testing of the XV-15 Tilt Rotor Research Aircraft built by Bell Helicopter Textron, developing data toward future use of the tilt-rotor transport in civil operations and also acquiring information to support military development of the JVX tilt-rotor.

NASA signed an agreement with the Navy for flight test of a supersonic oblique wing F-8 fighter, the operational version of which is built by LTV Aerospace and Defense Company. This is a follow-on to an earlier NASA program in which an experimental AD-1 aircraft, fitted with a wing that could be pivoted to various angles up to 60 degrees, was flown in a 38-flight series. The AD-1 was designed to explore—at the low end of the speed



3. In production for first deliveries in 1985 was the McDonnell Douglas MD-83, a standard-length, higher weight version of the MD-80.

4. McDonnell Douglas launched development of a shortened model of the MD-80 series, the MD-87; scheduled for airline service in 1987.

5. Selected to develop a Canadian helicopter industry, Bell Helicopter Textron started construction of a plant in Montreal for production of its Model 400 pictured.

6. June marked delivery of the first Schweizer-built 300C helicopter, being produced under license from Hughes Helicopters.

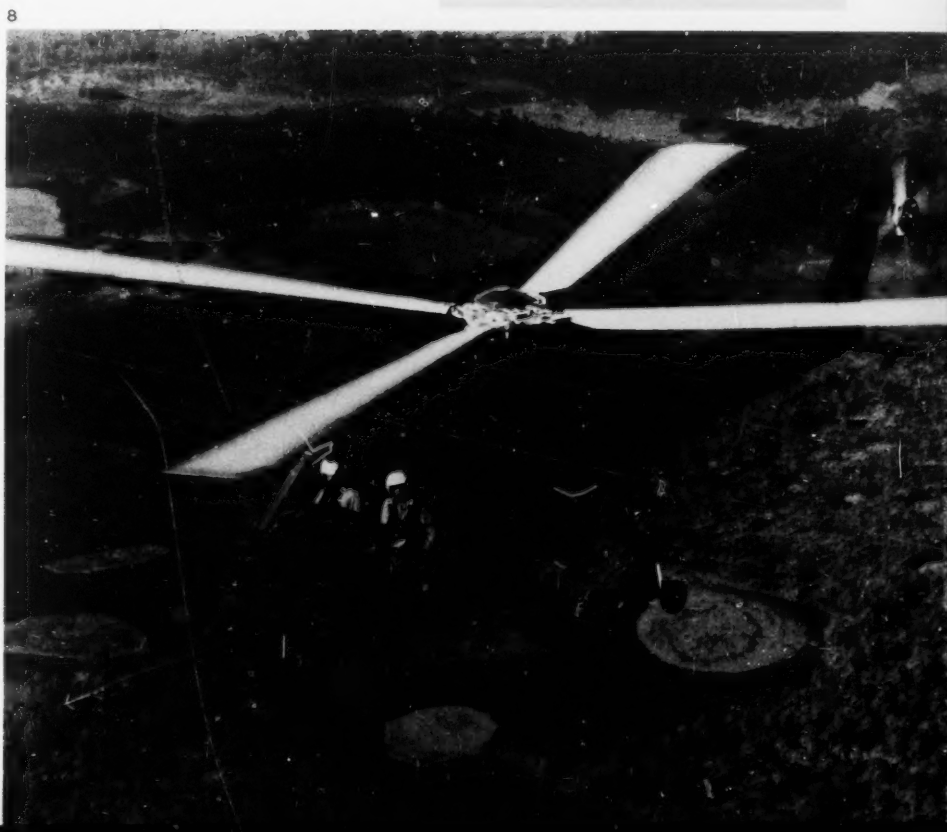
7. In production was the Boeing Vertol Model 234.

8. Sikorsky's ACAP all-composite-airframe helicopter made its initial flight in July.

range—the civil and military potential of the oblique wing concept, which offers potentially greater aerodynamic efficiency at supersonic speeds while retaining good efficiency and flying qualities at lower speeds. The new program will expand on AD-1 results at speeds up to Mach 1.4. NASA planned to award preliminary design contracts in 1985 toward wing fabrication in 1986 and flight tests beginning in 1988.

NASA's Advanced Turboprop Program progressed with selection of Allison Gas Turbine Division of General Motors for design, fabrication and testing of a gear box assembly to drive an advanced propfan. Hamilton Standard division of United Technologies was developing a nine-foot-diameter swept-tip propeller assembly. NASA intends to combine the propeller, gear box and a modification of an existing engine into a turboprop system to be test flown beginning in 1988.

Sikorsky's ACAP (Advanced Composite Airframe Program) helicopter made its initial flight in July and embarked on a 37-hour first phase flight test program. The ACAP became the first all-composite-airframe helicopter to reach flight status. Avtek Corporation's Avtek 400, an all-composite-airframe executive turboprop, made its first flight in September. These developments underlined the trend toward greater use of composite materials, generally lighter but stronger than the metals they replace, in all types of aircraft.



Aerospace '84

In 1984, aerospace industry sales increased five percent in inflation-adjusted *real* terms and the real sales level was the industry's highest since 1968. Both export sales and the international aerospace trade balance fell below the previous year's figures. Backlog and profits gained, and employment increased moderately.

Here is a summary, based on preliminary data, of the aerospace year 1984:

Sales. Total industry sales amounted to \$83.1 billion, up from \$75.8 billion in 1983. In current dollars, the 1984 sales volume was the largest in the industry's history; in real terms, it approached but fell short of the all-time peak year 1968. The industry recorded real increases in the military aircraft, missiles and space categories that more than offset a sharp decline in civil aircraft sales.

Sales of military aircraft increased from \$29 billion in 1983 to \$33 billion in 1984. Space sales, civil and military combined, continued their dramatic rise to \$16.8 billion, which compares with \$13.9 billion in 1983. Missile activity, at \$11.4 billion, was up \$2.3 billion. Civil aircraft sales amounted to \$9.8 billion, compared with \$12.2 billion in 1983, a 23 percent real drop. Sales of non-aerospace products and services totaled \$12.1 billion, up some \$500 million in current dollars but almost exactly level with 1983 in real terms.

Backlog. Orders on the industry's books at year-end 1984 totaled \$132.5 billion, an all-time high that represents a gain of more than \$16 billion during the year. Orders from the U.S. government—\$81.4 billion—accounted for more than 61 percent of the total.

International Trade. The strength of the U.S. dollar, delayed recovery for some foreign economies, and increased competitiveness of foreign manufacturers combined to reduce aerospace exports almost seven percent below the 1983 level; the figures were \$15 billion in 1984, \$16.1 billion in 1983. Aerospace imports rose to \$4.7 billion from 1983's \$3.4 billion, an increase of 37 percent overall and 53 percent in the civil aircraft category. The aerospace balance of trade was \$10.2 billion in 1984, down from \$12.6 billion in 1983.

Earnings. The aerospace industry recorded a record profit of \$3.6 billion, which compares with \$2.8 billion in 1983. Measured as a percentage of sales, the profit rate was 4.3 percent, well below the average of five percent for all U.S. manufacturing corporations.

Plant and Equipment. Aerospace industry expenditures for new plant and equipment increased sharply, from \$4.9 billion in 1983 to \$6.1 billion in 1984; as a percentage of sales, they increased from 6.5 percent to 7.4 percent. For 1985, projections indicate a further increase to \$6.7 billion, but a dip to 6.8 percent when expenditures are measured as a percentage of sales.

Employment. Aerospace employment increased moderately during 1984. The industry work force at year-end numbered 1,242,000, up from 1,171,000 at the end of 1983.

AEROSPACE REVIEW AND FORECAST 1984/85





Forecast

AIA estimates indicate that total sales in 1985 will reach \$97.9 billion, up 12.5 percent over 1984 in real terms, and that 1985 will become the industry's all-time peak year. The projection assumes continuing increases in industry military and space activities, coupled with a turnaround in the civil aircraft manufacturing sector, where activity has been depressed for several years. Employment is expected to rise to 1,280,000, which would be the highest level since 1969.

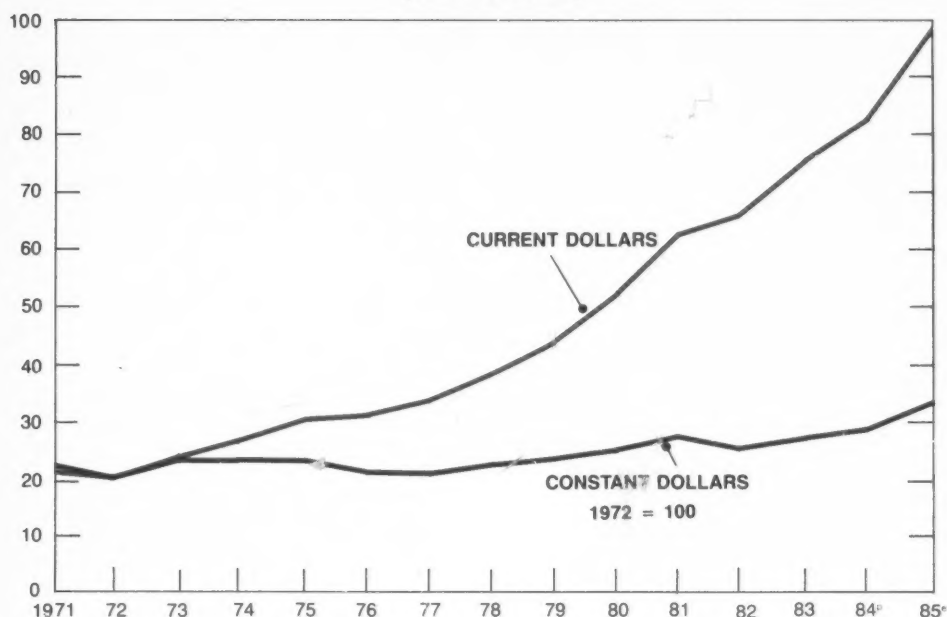
Defense. AIA projects that sales of aerospace products to the Department of Defense will top \$55 billion in 1985, an increase of more than 16 percent over 1984, with gains expected in all categories—aircraft, engines and parts, missiles and space. The record backlog of orders indicates that defense production activity will continue at high levels over the next two or three years. For the longer term, Congressional concern over budget deficits creates uncertainty as to future levels of defense spending. If public support for the Administration's defense buildup remains strong, AIA anticipates moderate increases in defense spending throughout the Reagan years, which would mean increasing industry activity into the 1990s.

Space. In 1984, sales of space-related equipment were up by more than 20 percent, on top of a 30 percent increase in the previous year. Space continues to be the most rapidly expanding segment of industry business, due largely to the significant growth in defense outlays for space systems. Assuming Congressional reaffirmation of NASA's space station plans and even moderate increases in the defense budget, AIA expects substantial sales growth in the two government-funded areas of space activity. Projections also indicate considerable growth in industry fabrication of commercial space systems, principally communications satellites but also including commercial launch systems, space and ground systems for commercial remote sensing operations, and free-flying platforms for commercial orbital processing experiments. The latter area, space processing aboard the Space Shuttle, the space station or associated platforms, suggests increased activity of an R&D nature for aerospace firms. All in all, with gains indicated in all three areas—military, NASA and commercial—the industry's space workload bids to become an even more significant proportion of total sales in the 1980s and beyond.

Civil Aircraft. Although civil aircraft sales fell sharply in 1984, AIA feels that the sales curve bottomed last year and should start a new ascent. The main reason is the improving financial health of the world's airlines, which has prompted some carriers to resume reequipment plans even though the industry as a whole has not fully recovered from the recent recession. This resulted in a surge of new orders for airline transports in 1984, at a level roughly double that of the previous year; these orders will become deliveries in 1985, 1986 and later years. AIA sees a similar upturn in overall civil aircraft production, including helicopters and general aviation aircraft. The association is projecting an increase of 40 percent—to \$13.8 billion—in 1985 civil aviation sales.

For the long term, AIA sees increased transport sales due to the projected growing demand for air transportation and requirements for replacement aircraft. Current market forecasts range from \$150 to \$250 billion over the next decade; even the lower figure far exceeds the value of all transports delivered over the last two decades. Depending on how large a share of this huge market U.S. companies will capture, commercial transport production could—within the next decade—increase to the highest level of all time.

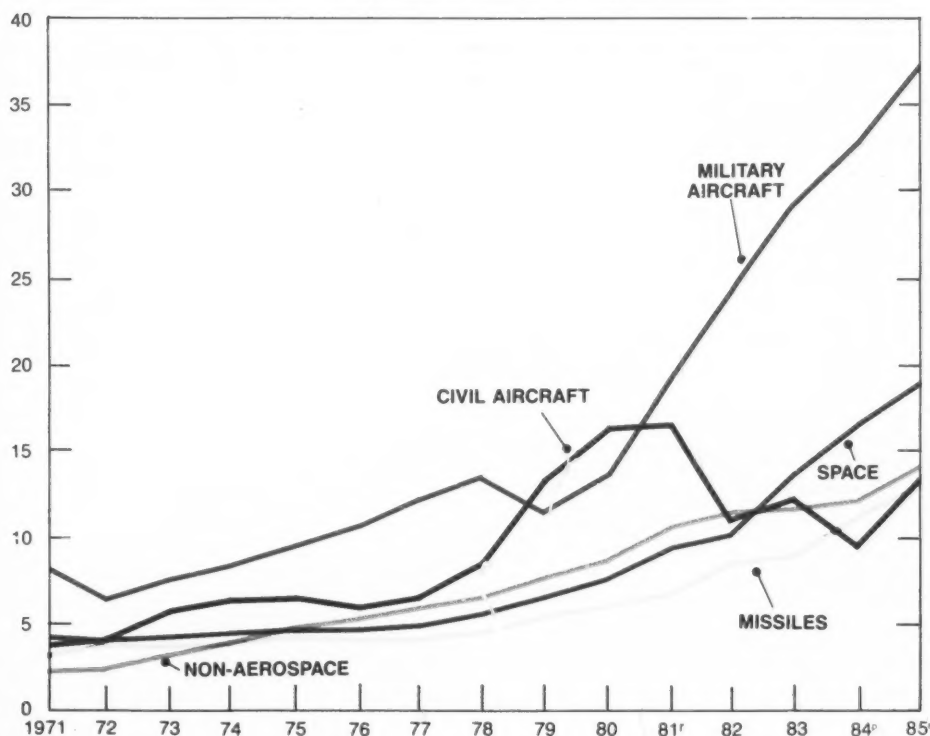
AEROSPACE INDUSTRY SALES (Billions of Dollars)



Source: Aerospace Industries Association
r Revised
p Preliminary
e Estimate

The aerospace industry's 1984 total sales of \$83.1 billion included \$71 billion in sales of aerospace products and services and \$12.1 billion in non-aerospace sales. The Department of Defense predominates in a breakdown of aerospace sales by customer; DoD sales amounted to \$47.7 billion, while sales to NASA and other government agencies totaled \$6.3 billion. Non-government sales of aerospace products were \$17 billion. For 1985, Aerospace Industries Association estimates total sales at \$97.9 billion, with \$83.7 billion of it—about 85 percent—in sales of aerospace products and services.

AEROSPACE INDUSTRY SALES BY PRODUCT GROUP (Billions of Current Dollars)

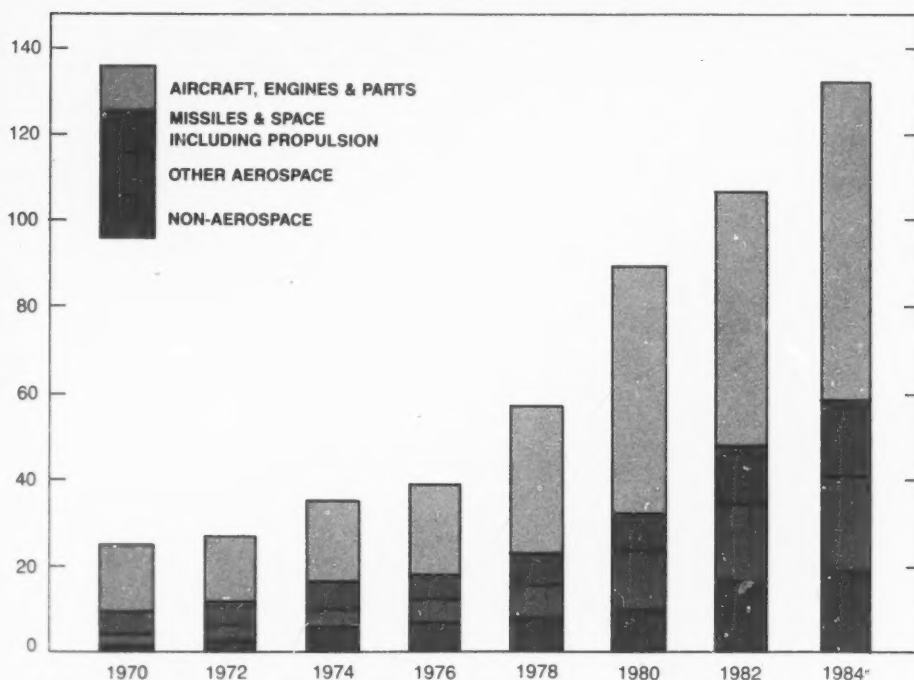


Source: Aerospace Industries Association
p Preliminary
e Estimate

As is customary, production of aircraft represented the largest single element of the 1984 sales volume—more than 51 percent. Sales of military aircraft, at \$33 billion, accounted for more than three-quarters of all aircraft sales. Civil aircraft sales, depressed for the past three years, amounted to \$9.8 billion. The largest gain in 1984 was in sales of missiles, up 25 percent in current dollars and 19.6 percent in real terms. Space related business increased 21 percent (15.5 percent with adjustment for inflation) and was second only to military aircraft among major sales categories. Non-aerospace sales were approximately level, up slightly in current dollars, down slightly in real terms. For 1985, AIA projects gains in all categories, led by a rebounding 40 percent increase in civil aviation sales, followed by increases of 18 percent in missiles, 17 percent in non-aerospace, 14 percent in space systems and 13 percent in military aircraft.

AEROSPACE INDUSTRY BACKLOG BY PRODUCT GROUP

(December 31, selected years, billions of current dollars)

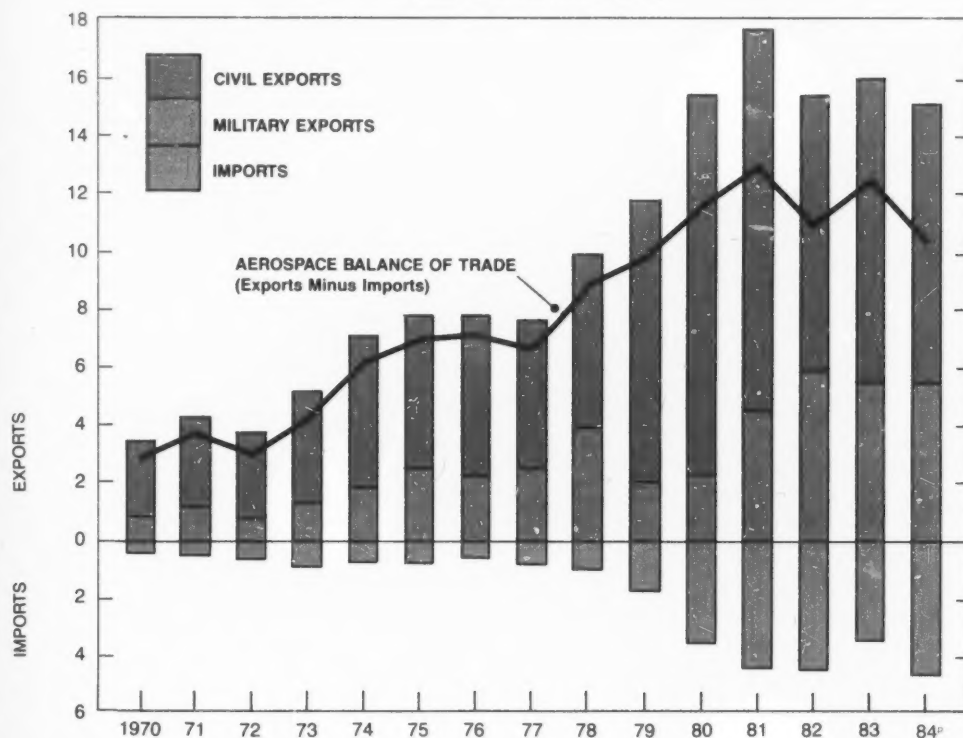


Source: Aerospace Industries Association, based on data from the U.S. Department of Commerce, Bureau of the Census and AIA estimates.

^e Estimate

AEROSPACE EXPORTS, IMPORTS AND TRADE BALANCE

(Billions of Current Dollars)



Source: Bureau of the Census.

^p Preliminary

The aerospace industry's backlog of orders at year-end was \$132.5 billion, up 14 percent above the \$116.3 billion on the books at the end of the previous year. Orders from the U.S. government — \$81.4 billion — accounted for more than 61 percent of the total. Orders for aircraft, engines and parts constituted almost 56 percent of the backlog. A breakdown of other backlog shows more than 13 percent in orders for missiles and space systems, about 16 percent in "other aerospace" systems and 15 percent in non-aerospace products and services.

The 1984 aerospace export volume declined seven percent to \$15 billion, which compares with the previous year's \$16.1 billion. Civil exports, including aircraft, engines and parts amounted to more than \$9.5 billion and military exports totaled more than \$5.4 billion. The decline in exports was due to reduced civil sales abroad, down almost \$1 billion from 1983; military exports remained at approximately the previous year's level.

Aerospace imports, at \$4.7 billion, rose 37 percent to their highest-ever level. The aerospace balance of trade was \$10.2 billion; that compares with \$12.6 billion in 1983 and the all-time high of \$13.1 billion in 1981.

CIVIL AIRCRAFT SHIPMENTS

Calendar Years 1968-1985

Year	NUMBER OF AIRCRAFT SHIPPED				VALUE (Millions of Dollars)			
	TOTAL	Commercial Transport Aircraft ^a	Helicopters	General Aviation	TOTAL	Commercial Transport Aircraft ^a	Helicopters	General Aviation
1968	14,922	702	522	13,698	\$ 4,267	\$3,789	\$ 57	\$ 421
1969	13,505	514	534	12,457	3,598	2,939	75	584
1970	8,076	311	482	7,283	3,546	3,158	49	330
1971	8,158	223	469	7,466	2,984	2,594	69	321
1972	10,576	227	575	9,774	3,308	2,660	90	558
1973	14,709	294	770	13,645	4,665	3,718	121	826
1974	15,326	332	828	14,166	5,091	3,993	189	909
1975	15,251	315	864	14,072	5,086	3,779	274	1,033
1976	16,420	222	757	15,450	4,592	3,078	285	1,229
1977	17,913	155	848	16,910	4,451	2,949	251	1,551
1978	18,962	241	904	17,817	6,458	4,308	328	1,822
1979	18,460 ^a	376	1,020 ^a	17,055	10,644	8,030	403	2,211
1980	13,634	387	1,366	11,881	13,058	9,895	656	2,507
1981	10,916	387	1,072	9,457	13,223	9,706	597	2,920
1982	5,085	232	587	4,266	8,610	6,246	365	1,999
1983	3,354	262	401	2,691	9,739	8,000	269	1,470
1984 ^{re}	2,973	185	418	2,370	7,660	5,669	336	1,675
1985 ^{re}	3,227	287	540	2,400	11,171	8,735	536	1,900

Source: Aerospace Industries Association, based on company reports, data from the General Aviation Manufacturers Association, and AIA estimates.

a Includes all U.S. manufactured civil jet transport aircraft plus the turboprop-powered Lockheed L-100.

(o) Preliminary.

(e) Estimate.

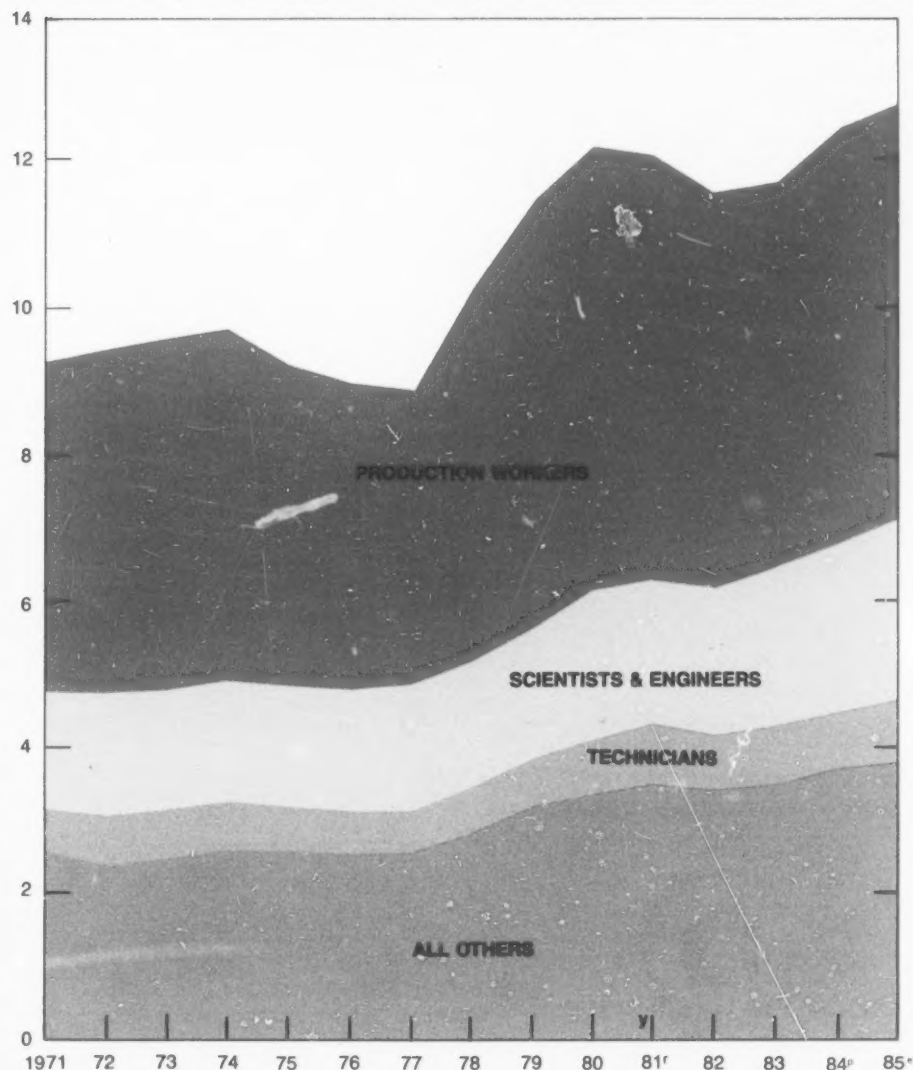
r Revised.

Total shipments of civil aircraft declined in both numbers and dollar value. The industry delivered 2,973 aircraft, down 381 units from 1983 to a level representing less than 16 percent of total shipments in the peak year (1978). Total dollar value was \$7.7 billion, some \$2 billion lower than in 1983. The \$7.7 billion figure is the value of complete aircraft delivered during the year; it differs from the earlier-mentioned civil aircraft sales volume of \$9.8 billion in that the latter figure includes the value of spare engines and parts.

Commercial transports accounted for 74 percent of the total value of civil aircraft deliveries. The industry delivered 185 transports (down from 262 in 1983) worth \$5.7 billion (down from \$8 billion). General aviation shipments dipped slightly to 2,370 units (down from 2,691) but dollar value increased to \$1.7 billion (up from \$1.5 billion). Helicopter deliveries increased by 17 units to 418; dollar value was \$336 million, up from 1983's \$269 million. Projections for 1985 show total shipments of 3,227 aircraft worth \$11.2 billion, with both dollar value and unit gains expected in all categories.

AEROSPACE EMPLOYMENT

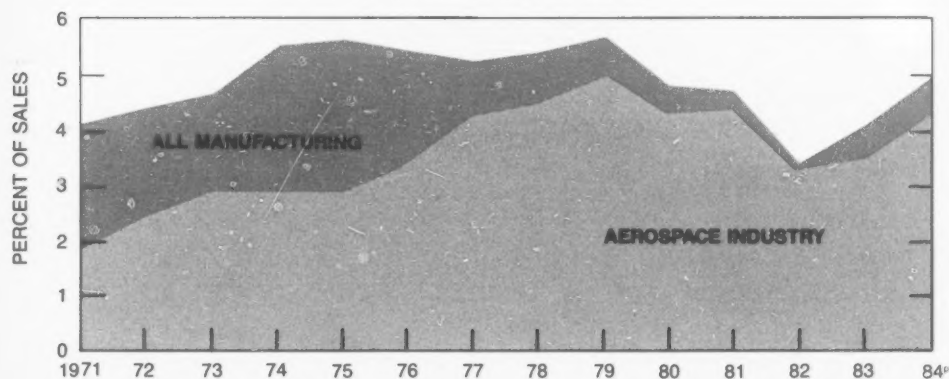
(hundreds of thousands of employees as of December 1971-85)



Source: Aerospace Industries Association, based on data from the U.S. Department of Labor, Bureau of Labor Statistics, "Employment and Earnings" and AIA Semi-Annual Survey of Aerospace Industry Employment.

p Preliminary.
e Estimate.

NET PROFIT AFTER TAXES



Source: Aerospace Industries Association

r Revised
p Preliminary

At year-end 1984, the aerospace industry's labor force numbered 1,242,000, up from 1,171,000 at the end of the previous year. The largest increase was in production workers, up 36,000 to 564,000. The number of scientists and engineers increased by 13,000 to 229,000 and employment of technicians was up by 5,000 to 84,000. There was also an increase of 17,000 in the "all others" category, which totaled 365,000 at year-end. For 1985, AIA projects an overall gain of 38,000 to a year-end total of 1,280,000.

The aerospace industry recorded a profit after taxes of \$3.6 billion in 1984, up from \$2.8 billion in 1983. Measured as a percentage of sales, the profit rate was 4.3 percent, compared with 3.5 percent in the previous year and an average of 4.1 percent for the five-year period 1979-83. The 1984 figure compares with an average profit rate of five percent for all U.S. manufacturing industries.



MEMBERS

Abex Corporation
Aerojet-General Corporation
Aeronca, Inc.
Allied Corporation
Aluminum Company of America
Avco Corporation
The Boeing Company
Colt Industries Inc.
 Chandler Evans Inc.
 Menasco Inc.
 Delevan Corporation
Criton Technologies
E-Systems, Inc.
Ex-Cell-O Corporation
FMC Corporation
The Garrett Corporation
Gates Learjet Corporation
General Dynamics Corporation
General Electric Company
General Motors Corporation
 Allison Gas Turbine Division
The BF Goodrich Company
Goodyear Aerospace Corporation
Grumman Corporation
Hercules Incorporated
Honeywell Inc.
Hughes Aircraft Company
IBM Corporation
 Federal Systems Division
ITT Defense Space Group
 ITT Aerospace/Optical Division
 ITT Avionics Division
 ITT Defense Communications Division
 ITT Federal Electric Corporation
 ITT Gilfillan

Kaman Aerospace Corporation
Lear Siegler, Inc.
Lockheed Corporation
LTV Aerospace and Defense Company
The Marquardt Company
Martin Marietta Aerospace
McDonnell Douglas Corporation
Morton Thiokol, Inc.
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Rohr Industries, Inc.
The Singer Company
Sperry Corporation
Sundstrand Corporation
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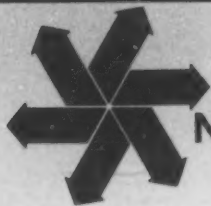
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- SDI — WHAT, HOW, WHY
- 1986: A BIG YEAR IN SPACE



Notable views of notable people on aerospace matters...

aerospace perspectives

Senator Barry Goldwater, Arizona, chairman of the Senate Armed Services Committee, writing in the *Des Moines Register*:

"The defense budget is not sacrosanct. Some reductions will doubtless be necessary this year in light of the federal deficit. But given how far we've come in improving our defenses, how those reductions are applied is terribly important. Superficial, impulsive schemes like Senator Charles Grassley's defense freeze, are far better suited to bumper stickers than the realities of the dangerous world in which we live. When reductions are made, it is vital they be based on thorough analysis and guided by the best professional judgment available. Our own taxes and our children's security depend on it."

Edward L. Rowny, special advisor to the President and to the Secretary of State on arms control matters, writing in the *New York Times*:

"The Soviet Union seems determined to prevent American research on strategic defense, research that the Russians themselves have long been conducting . . .

"One often hears the question 'Why should Moscow reduce its offensive weapons while we're pushing defense research?' First, we are not alone in efforts to explore the feasibility of ground- and space-based defense against ballistic missile attack. Long before President Reagan's speech in 1983 outlining the Strategic Defense Initiative, the Soviet Union was engaged in a large-scale defense research program.

"Further, the Russians have been violating the anti-ballistic missile treaty. Given the pattern of their many activities in strategic defense, we are concerned that they may be establishing a base for a nationwide ballistic missile defense capability. Such a move, combined with an erosion in the offensive balance, would have severe consequences.

"Finally, as both sides have acknowledged, research is not verifiable and hence not negotiable. But the Russians seem determined to continue their own research while trying to stop ours. The freeze they propose on offensive forces would simply codify existing Soviet advantages."

Robert E. Hunter, director of European studies at the Georgetown University Center for Strategic and International Studies, writing on "The Relevance of American Power" in the *SAIS Review*:

"It has been increasingly evident for more than a decade that the world of military power and security also coexists with the world of economic power and security. This second world demands 'equal time' to a degree unparalleled in the postwar world. In absolute terms, of course, U.S. economic power has increased steadily since World War II. But so has that of other nations, so that our margin of advantage has diminished relatively; we have gone from being a giant among pygmies to being first among near-equals. . .

"Changes in the global economy also have long-term implications for U.S. power and influence within the Western alliance. For the early part of the postwar period, there was

no inherent economic contradiction within the Western alliance, because rebuilding Western Europe was an essential part of security and a net addition to U.S. power. There was also a common interest in one another's prosperity and in the functioning of the global economy. Yet about the time of the collapse of the Bretton Woods system in 1971—and not coincidentally—economic competition across the Atlantic began seriously to rival the motive of common interest. Today, in fact, differences over economics have become one of the central systemic trends in the Western alliance. Such differences could weaken it economically and politically and, as a consequence, weaken U.S. power as represented by Western solidarity."

Harry J. Gray, chairman and chief executive officer of United Technologies Corporation, in the keynote speech to the National Conference of the National Security Industrial Association in Washington, D.C.:

"In the case of critical military technology, we've got to be ultra-vigilant to keep vital knowledge from the wrong hands. In relationships with partners in allied countries, we have to work closely with them and their governments to assure tight-fisted security. We have to be more restrictive in sharing technology with some allies than with others, depending on their policies on selling weapons to other countries.

"Clearly, our national interests must come first at all times. We must be alert to government policies, however, that place unnecessary and excessive restrictions on technology. Unrealistic barriers to technology exports handcuff America economically and degrade us in the eyes of our friends and allies.

"We must be certain that any technologies we withhold for our exclusive use are critical to our interests and are uniquely ours. It is folly to deny a friendly country technology it can get elsewhere . . .

"Government legislation and regulation must take into account these realities. Unnecessary restrictions on knowledge, exports and international partnerships are damaging to the U.S. in the long run. They undermine our economic and security interests. They impair technological advancement. They undercut job creation. They damage relations with other countries that share our economic interests as well as the burden of collective security . . . We need legislation to provide the kind of effective controls that don't generate counterproductive consequences."

Vorne Orr, Secretary of the Air Force, in an address to the Institute for Contemporary Studies in Los Angeles, California:

"If Ronald Reagan gets all he's asked for Fiscal Year 1986, your defense budget will amount to about 6.3 percent of the Gross National Product. Historically, that's not high. Under President Kennedy, we spent eight percent of our GNP for defense and under President Eisenhower we spent around 10 to 11 percent—almost double the percentage of defense spending that has suddenly become 'a burden we can't bear.'"

AIA aerospace

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PRESIDENT • Karl G. Harr, Jr.

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FOR PUBLIC AFFAIRS • John F. Loosbrock

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OF PUBLIC RELATIONS • David O. Schillerstrom

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EDITOR • John F. Loosbrock

ASSOCIATE EDITORS • James J. Haggerty

Ellen Kelly

Jean Ross Howard

David O. Schillerstrom

ART DIRECTOR • James J. Fisher

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10 1986: A BIG YEAR IN SPACE

By James J. Haggerty

16 NEW GOALS FOR AERONAUTICAL R&D

On the cover: The artist's concept shows an Earth-generated laser beam being reflected toward a high-altitude target by a space-based mirror. This is one of a number of ballistic missile defense concepts being explored in the Strategic Defense Initiative research program (see page 2).

The purpose of AEROSPACE is to:

Foster understanding of the aerospace industry's role in insuring our national security through design, development and production of advanced weapon systems.

Foster understanding of the aerospace industry's responsibilities in the space exploration program.

Foster understanding of civil aviation as a prime factor in domestic and international travel and trade.

Foster understanding of the aerospace industry's capabilities to apply its techniques of systems analysis and management to solve local and national problems in social and economic fields.

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A Perspective on the Defense Industry

BY KARL G. HARR, JR.

President, Aerospace Industries Association

The following is a reprint of an article by Dr. Harr
in "The Debate" section of USA Today in April:

Defense and space business is paid for by the taxpayer, involves vital national security interests, and is controlled by the government customer. Thus, defense is the "people's business" and both the media and the political establishment justly feel they have a right and a duty to monitor it closely.

It is important to place in perspective the essential characteristics of the defense industry and the procurement process under which it operates.

The defense industry is large, with annual sales well over \$100 billion. It is enormously complicated, charged not only with producing but *inventing* complex systems at the cutting edge of technology. Its high-tech products must meet extraordinary standards of performance and reliability.

It is free enterprise that must serve two masters, the government customer and the corporate stockholders. It is perhaps the most closely audited and scrutinized industry in the history of our nation.

But, as a peacetime entity, it is a young industry, born in the wake of World War II to counter a Soviet threat and publicly supported, in the years since, only as long as and to the extent that such a threat was perceived.

There were no precedents to guide the creation of a large peacetime defense establishment, so development of the procurement process has been largely a matter of experimentation, trial and error, lesson-learning in a constantly changing defense environment.

The government and industry have spent 30 years working out the necessarily complicated rules of the game. That they have substantially done so is evidenced by the exceptional performance of the industry.

It has produced—and continues to produce—the world's finest weapon systems. It has made tremendous advances in weapons capabilities, reliability, and performance as well as in deliveries within cost and schedule.

In addition, industry-developed equipment has enabled the USA to lead the world in space exploration and exploitation and to dominate world-wide sales of airline transports. Much government/industry effort has gone into the system that made these considerable achievements possible.

Admittedly, the system has on occasion come up short: a product is delivered late, costs too much, or fails to meet performance standards.

Industry can take its share of the blame. So can the Pentagon. So can the Congress. Such irregularities must be and are being corrected.

But widely publicized abuses are anomalies, not the norm. They must not be allowed to distract our attention from the main task of ensuring the efficient functioning of a process so vital to the nation's security and economy.



THE WHY, WHAT, AND HOW OF THE STRATEGIC DEFENSE INITIATIVE

By Brigadier General Robert R. Rankine, Jr., USAF



General Rankine holds three separate jobs within the Air Force, all of them related to the Strategic Defense Initiative (SDI). He is special assistant for SDI to the Deputy Chief of Staff, Research, Development and Acquisition; special assistant, SDI, to the Vice Commander, Air Force Systems Command; and he is responsible, at USAF headquarters, for the Air Force's science and technology program. In recent assignments prior to taking up his present duties, he served in the Office of the Under Secretary of Defense for Research and Engineering as assistant for directed energy weapons and SDI planner, and as Deputy Director of the Strategic Defense Initiative Organization. This article is based on a speech to the American Institute of Aeronautics and Astronautics.

In his March 1983 defense policy speech, President Reagan discussed his continued support for strategic offensive modernization and arms control efforts. He also challenged the scientific community to determine the feasibility of developing systems capable of destroying ballistic missiles in flight, thus providing an alternative to sole reliance on offensive nuclear retaliation as the basis for strategic deterrence, and leading to the ultimate goal of eliminating the threat of ballistic missiles.

Immediately following that speech, the President directed that two studies be accomplished to investigate the policy and the technology implications of an effective ballistic missile defense system. From these two studies emerged the basis for a long-range research program. In October 1984, the Congress appropriated funds for the Strategic Defense Initiative, financing the new hope for the future, first expressed by the President less than nineteen months earlier.

To best understand the scope and breadth of this initiative, I will answer three questions:

First, **why?**—which will address the strategy and policy implications of an effective ballistic missile defense.

Second, **what?**—which will describe the scope and priorities of the research program underway to determine technical feasibility.

And lastly, **how?**—which will describe

the procedures we have established to centrally plan and control the program, yet decentrally execute the technology efforts.

In the long term, we have confidence that SDI will be a crucial means by which both the U.S. and the Soviet Union can safely agree to very deep reductions and eventually even the elimination of ballistic missiles and the nuclear weapons they carry. This does not represent a shift from the basic deterrent strategy of the U.S., but represents a new means for enhancing deterrence. That policy, in effect since the beginning of the nuclear era, has not changed in its fundamentals, but our ability to deter has hinged upon differing military capabilities, ranging from a balanced nuclear bomber and air defense capability in the fifties to almost total reliance on the threat of retaliation in the eighties. The shifts in the basis for deterrence have been forced by the development of various nuclear delivery systems and not by fundamental changes in policy.

The emergence of nuclear tipped ballistic missiles in the late fifties and sixties changed the timing of nuclear warfare and thus reduced the importance—in the view of many U.S. leaders—of the need for air defenses. Because ballistic missiles are fast and unrecalable and are becoming increasingly accurate, they potentially are the most destabilizing of the currently deployed systems—particularly the ICBMs which may be tar-



This overview of the Strategic Defense Initiative research plan illustrates the four-layered defense system contemplated: attacking ballistic missiles in their boost and post-boost phases, during midcourse flight and in the terminal portion of their trajectories as they descend into the atmosphere.

Laser and particle beam systems are among the major candidates for directed energy weapon (DEW) systems, which attack ballistic missiles at or near the speed of light. Lasers are designed to kill by burning a hole in the target vehicle; particle beams penetrate the target's interior to destroy electronic and other internal components.



SPACE BASED LASER



GROUND BASED LASER



NEUTRAL PARTICLE BEAM



X-RAY LASER



An example of a directed energy weapon is the space-based laser system, which offers the opportunity to intercept ballistic missiles in the boost phase, before they can deploy their warheads and decoys. Since laser light penetrates the atmosphere, this type of system may also have potential in defense against airbreathing missiles or aircraft.

geted against each other. Therefore, a ballistic missile defense capability has the potential of increasing deterrence and adding to stability, by increasing substantially the uncertainties in the success of nuclear attack by an enemy, thoroughly confounding his targeting strategy, thus significantly reducing or eliminating the utility of preemptive attack. The system need not be perfect to accomplish this objective, but must meet three important criteria:

- First, it must be effective against the systems and countermeasures that exist or could be deployed.

- Second, it must be sufficiently survivable that it would not encourage an attack on the system itself by either enemy defensive or offensive systems. If it were not survivable, then it might invite a defense suppression attack as a prelude to an offensive attack, thereby decreasing rather than increasing crisis stability.

- Third, in addition to being effective and survivable, defenses must be able to be expanded to maintain effectiveness at lower cost than any proliferation or countermeasure attempts to overcome them. If that were not the case, the existence of defenses would encourage rather than discourage proliferation. Providing for cost-effective and survivable defense is the key challenge to the Strategic Defense Initiative technology program and illustrates the need for research before an informed decision to begin system development is possible.

In the late sixties and early seventies, the United States had done developmental work on an anti-ballistic missile system known as Safeguard. That system, which was deployed in the mid-1970s, was dismantled shortly thereafter, due in part to the fact that it could not maintain effectiveness against proliferation. The U.S. also hoped that not deploying U.S. defenses permitted by the ABM treaty would encourage the Soviet Union not to build more ballistic missiles. It did not. Not only did the Soviets continue to build ballistic missiles, they also relentlessly pursued technology for defending against ballistic missiles.

An example of this was shown in the U.S. Department of Defense publication *Soviet Military Power 1984*, which described a directed energy R&D site at Sary Shagan in the central Soviet Union that not only could provide an antisatellite capability today, but possibly a prototype for an ABM system to be deployed in the future. The Soviets have currently the only operational ballistic missile defense, which is located around Moscow. The system is for terminal defense and similar in many ways to the Safeguard system that we had deployed in the early 1970s. The Soviets are presently modernizing that Moscow system and have developed a rapidly deployable ABM system which has potential for deployment as a nationwide ABM system.

Of even greater concern however, the Soviets have been pursuing for many

years extensive development of technologies which have potential for advanced ballistic missile defense applications. Whereas the United States has been developing basic laser technology, the Soviet Union is exploring many laser technologies. In the particle beam area, the most advanced U.S. technology is derived from Soviet research reported in their technical literature several years ago.

The Strategic Defense Initiative program thus provides us a hedge against what might otherwise be a Soviet technical surprise. A unilateral Soviet deployment of such advanced defenses, in conjunction with its offensive deployments and its air and civil defense efforts, could result in a significant change in Soviet military capability and could adversely affect the security of the United States and its allies.

Some of the opponents of the Strategic Defense Initiative have argued that the research and technology program currently under way is inconsistent with the ABM treaty and conflicts with arms control in general. Quite to the contrary, the initiative is totally consistent with current U.S. ABM treaty obligations. The initiative contemplates only research and experimentation on a broad range of defensive technologies to provide the basis for a decision in the future whether or not to develop systems which would provide an effective ballistic missile defense capability.

As we look toward the future, effec-

tive defenses have the potential of decreasing the value of ballistic missiles as instruments of national strategy, thus increasing the likelihood of negotiating reductions in those ballistic missiles. Negotiated reductions in offensive forces, in turn, will enhance the effectiveness of the defenses; we have created a defensive spiral in which both parties would be more willing to negotiate further reductions. Thus defenses couple synergistically with arms control leading to attainment of the ultimate goal stated by the President: to eliminate all threats posed by nuclear ballistic missiles.

An important aspect of the entire initiative is the fact that the United States is in no way decreasing its commitment to the protection of its allies but, in fact, is examining technologies for defense not only against ballistic missiles that can hit the United States, but against shorter range ballistic missiles that can

strike our allies. We are consulting closely with our allies.

The emphasis in the Strategic Defense Initiative on defending against ballistic missiles is due to their potential to increase instabilities. But while the slower moving systems, such as cruise missiles and bombers, are less threatening in this regard, there are separate efforts under way in the services to examine the technologies required to defend against these weapon systems as well.

Having described the rationale for the program, I will now describe its technical scope and what has changed over the last 10 years that has made defense against ballistic missiles both more realizable and more effective. To do this, it is important to understand the flight path of a ballistic missile and the various regimes in which ballistic missiles can be attacked. It starts in the boost phase, in which the ballistic missile, being thrust

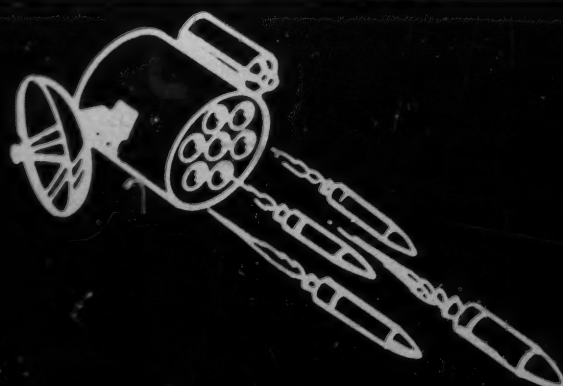
by a large chemical rocket, slowly rises from the face of the Earth enroute to its targets. This phase can be characterized by an intensely bright plume which provides a very large characteristic infrared signature. In this phase, the ballistic missile still has all its warheads attached. Attack in this phase could provide large multiplier effects and would thus provide maximum leverage from a defensive point of view.

In the next phase, post-boost or the bus deployment phase, warheads and penetration aids are deployed in such a way as to attempt to confuse the defenses. This phase is followed by the longest phase, the mid-course phase. The warheads and penetration aids coast on a ballistic trajectory from minutes to tens of minutes on the way to their target. In the last phase—the terminal phase—the warheads and the decoys re-enter the atmosphere. Discrimination

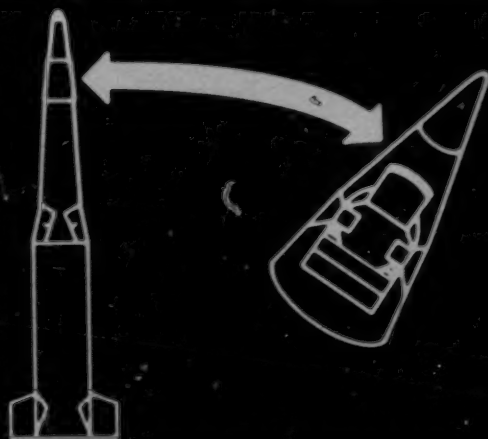
The SDI program involves research on four kinds of kinetic energy weapons, or "smart bullets," each equipped with a small computer and a lightweight sensor: the endoatmospheric interceptor, intended to hit an incoming missile in the terminal phase of its trajectory; the exoatmospheric interceptor, designed for intercept outside the atmosphere in the missile's midcourse phase; small chemical rockets, emplaced on space-based "pods," for intercept in the boost and midcourse phases; and the hypervelocity weapon, also intended for boost/midcourse intercept.



ENDOATMOSPHERIC INTERCEPTOR



SPACE-BASED CHEMICAL ROCKET



EXOATMOSPHERIC INTERCEPTOR



HYPERVELOCITY LAUNCHER



Among kinetic energy weapon systems being investigated is the space-based hypervelocity launcher, or rail gun, which employs electrical forces rather than chemical propellants to fire "smart" projectiles. The electric gun may be able to generate projectile velocities of more than 20 miles a second, compared with five miles a second for chemical rockets.

is facilitated in this phase by the differing re-entry dynamics and signatures of the warheads and decoys.

Attacking ballistic missiles in all four of these phases is what is known as a layered defense system. This is a defense-in-depth approach that is not new to the military. For example, it is similar in concept to the approach used by the U.S. Navy to protect a carrier task force. We have the F-14 Tomcat attacking aggressors at long range using the Phoenix missile system; at shorter ranges, using Sparrow and Sidewinder missiles; then followed up by surface-to-air missiles from the support vessels and finally by the Phalanx gun system. Layered defenses relieve the effectiveness requirements on each individual layer and are more resistant to countermeasures.

Certain functions need to be accomplished in each of these four phases for ballistic missiles to be effectively attacked; first, detection, acquisition, discrimination and kill assessment; second, pointing and tracking; third, interception and destruction, and fourth, battle management. The scope of the Strategic Defense Initiative program can be discerned by identifying weapon system concepts for each function in each phase. The collection of technologies that will per-

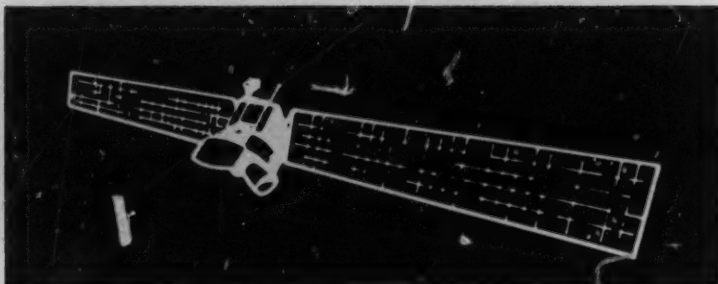
mit the realization of these concepts defines the technical scope of the program. As an example—in the boost phase—the requirements for detection, acquisition, discrimination and kill assessment could be accomplished by taking advantage of the very bright signature of the booster itself. Space-based infrared sensors could detect and track the booster and thus handoff to a boost phase interception and destruction capability which would employ either directed energy or kinetic energy. The technologies which support such a concept include focal plane arrays, light-weight optics and signal processing for space applications; programs in each of these technical areas are now being pursued under the central management of the Strategic Defense Initiative program. All of these key technologies were being pursued previously; hence, the Strategic Defense Initiative is not a new program, but an entirely new focus for a collection of relevant programs.

For better appreciation of the scope of the program, let me describe some notional architectures for the sensors and weapons that might fulfill the functional requirements of a multi-layered defense.

In the sensor area, we are looking at

five interleaved system concepts—first, a boost-phase detection and tracking system which would detect launches of ballistic missiles. In the mid-course area, we perceive the need for a "birth-to-death" tracking and fire control system to provide the tracking of the reentry vehicles from deployment to reentry. Also in the mid-course, we see the need for a laser or radar system to image the post-boost vehicle to observe reentry vehicle and decoy deployment and thus discriminate between the two. In the terminal phase, two systems are currently envisioned, one an airborne optical adjunct which would provide for long-range infrared tracking and discrimination of the reentry vehicles and decoys. And lastly, a ground-based imaging radar which would provide endoatmospheric discrimination of reentry vehicles and decoys.

In the kinetic energy weapons area, both ground-based and space-based assets would provide for attack of ballistic missiles in all phases. In the boost-phase, space-based projectiles propelled by chemical rockets or electromagnetic launcher systems would provide a capability of attacking the booster while it is still under power. These same systems would also be capable of attacking post-

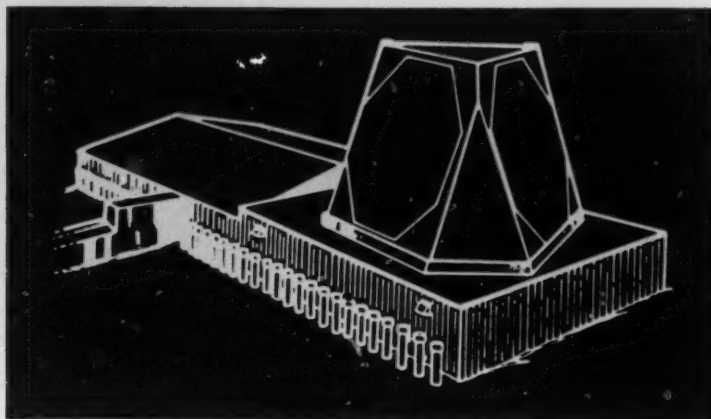


SPACE SURVEILLANCE

The SDI Sensors Program is organized into two parts: technology development for new sensors, imaging techniques and associated data processors that will aid in discriminating decoys from warheads; and experimental demonstrations to validate new technologies and provide confidence that full scale development can be initiated.



AIRBORNE OPTICAL SENSOR



TERMINAL RADAR

boost vehicles and reentry vehicles during midcourse flight. In the terminal and late mid-course area, ground-based interceptors would provide a non-nuclear hit-to-kill capability to destroy the reentry vehicles on a one-to-one basis.

Last June, the homing overlay experiment (HOE) conclusively demonstrated the technology of hit-to-kill intercept of reentry vehicles. Some new technology breakthroughs have recently occurred in the hypervelocity launcher area. We have been able to accelerate projectiles from a repetitively fired electromagnetic railgun launcher up to several kilometers per second. In addition, pre-programmed maneuvering projectiles have functioned after sustaining accelerations in excess of 50,000 Gs.

Directed energy weapons are being investigated primarily to attack ballistic missiles in either the boost or post-boost phase. Several options currently exist. Chemically powered space-based lasers might provide long range, speed-of-light intercept and kill of both boosters and post-boost vehicles. Alternatively, ground-based excimer or free electron lasers could bounce their energy off space-based mirrors and thus be able to attack a large number of boosters without the need to put the laser device in

space. Neutral particle beams can penetrate deeply into the ballistic missiles, causing catastrophic damage to internal components. Recent work on the Navy's Mid-Infrared Advanced Chemical Laser (MIRACL) has demonstrated not only the highest power, but now also the highest brightness of any laser in the free world. This laser, at the White Sands Missile Range, will be a work horse for the Strategic Defense Initiative, allowing us to determine by actual testing the trade-offs between booster hardening and laser brightness.

Not everything within the broad technical scope of the Strategic Defense Initiative is equal in priority. Five priority technology areas can be defined which provide the keys to an effective defense. First is the definition of weapon concepts for boost-phase and post-boost vehicle intercept. Directed energy weapons such as lasers and particle beams have the promise to provide for long-range intercept of the booster and the post-boost vehicle at or near the speed of light. Kinetic energy projectiles propelled to hypervelocity by chemical propellants or electro-magnetic force also offer potential for such early intercepts. Concurrent with the pursuit of technologies that will make such weapons possible is

the definition of the lethality required, not only against currently deployed Soviet ballistic missiles, but also against new missiles built to incorporate countermeasures intended to overcome the effectiveness of these new weapons.

In the mid-course area described earlier, the key to cost-effective defense is discrimination of reentry vehicles from the decoys. If discrimination can be accomplished with sufficiently high confidence, mid-course intercept can be obtained with reasonable numbers of interceptors. By simultaneously advancing technology to reduce the cost of the mid-course interceptors, one can trade off the effectiveness of the discrimination with the cost of attacking more expensive decoys in addition to true reentry vehicles.

Survivability of space-based defense assets is a key to the program. Since these systems must be sufficiently survivable to preclude a pre-emptive attack upon them, major emphasis in the Strategic Defense Initiative program will be to develop survivability measures for the space-based assets to include such things as electronic countermeasures, self-defense, decoys and hardening. However, we are not only looking at the technology to enhance the survivability

of single satellites, but are also exploring the full range of tactics to provide for overall mission accomplishment without the dependency on any one satellite. Tactics of this kind include such things as escort defense, orbit selection, proliferation and maneuver.

The last, and not the least, most important priority technology is in the area of battle management. In the past, the development of high-speed computational capability for the real-time battle management of such a system would have precluded the development and deployment of such an effective layered defense. Today's computer processing capabilities, which are growing by an order of magnitude every three to four years, promise to provide the technology sufficient to support such a system by the turn of the century. Of greater concern, though, is the issue of software preparation and testing. We currently do not have the capability to build and validate the software necessary in a timely manner. Hence, research on "software development tools"—that is, computer programs that can write and test

new computer programs—are receiving high priority attention.

With the scope and the priorities of the Strategic Defense Initiative research program thus defined, let me turn now to the question of how the program is being executed. The Congress appropriated \$1.6 billion for the Strategic Defense Initiative for Fiscal Year 1985—\$1.4 billion for the Department of Defense and \$200 million for the Department of Energy. Although this was only 80 percent of what the President had requested, it has nevertheless permitted a focused, centrally-managed beginning for the Strategic Defense Initiative. We believe that the central management of those funds by General Abrahamson's Strategic Defense Initiative Organization (SDIO) has introduced economies and efficiencies which enable us to get more for that money than if the pieces were pursued separately.

The overall management of the program is characterized by centralized planning and control by the Strategic Defense Initiative Organization with decentralized execution by the Army, Air Force, Navy,

DARPA, Defense Nuclear Agency and the Department of Energy.

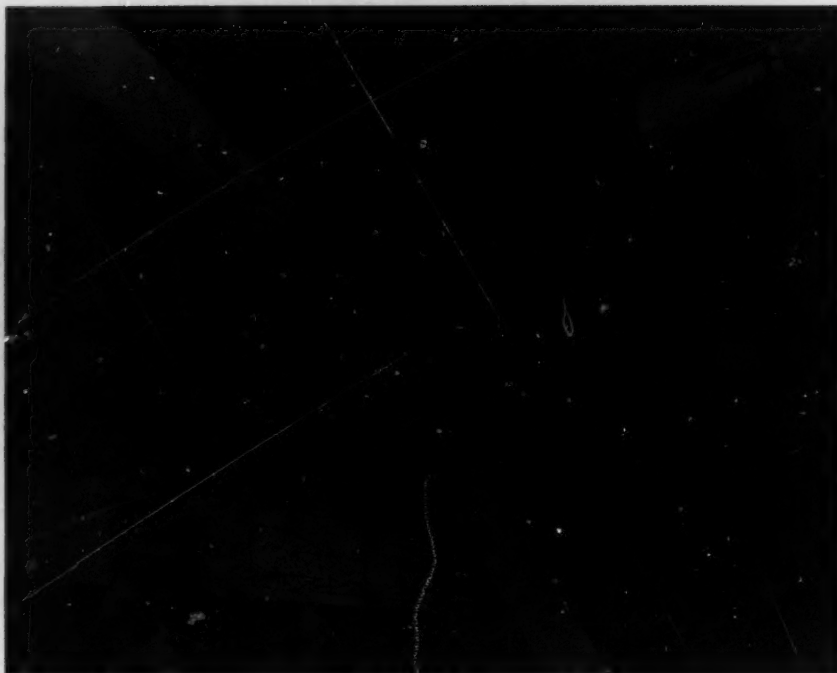
In FY 85, the two largest executors are the Army and Air Force, with 40 and 35 percent respectively, of the DoD portion of the program. The Army and the Air Force were able to undertake such large portions of work in Fiscal Year 1985 because the work had actually begun in previous years. That is, the Strategic Defense Initiative provided a new context and focus for the Army's prior work on ballistic missile terminal defense and the Air Force's prior work on space surveillance and space defense. For example, the Air Force was developing technology for detecting and tracking satellites using long-wavelength infrared space-based sensors. This basic technology, with improvements in sensitivity and resolution, provides the basis for reentry vehicle tracking.

Based upon the \$3.7 billion budget request for the DoD part of the program submitted to Congress, the distribution of the funds in Fiscal Year 1986 will remain much the same as in 1985.

For the ease of presentation and man-

Experiments envisioned include demonstrations of space-based sensors emplaced at high altitude (illustration) for boost phase surveillance and tracking, and a midcourse surveillance system that will enable detection, tracking and discrimination of all objects in low Earth orbit, including ballistic missile warheads, decoys and debris.





Among supporting technologies being investigated in the SDI program is a space-based system for generating high power levels. The artist's concept shows the ST-100 Space Nuclear Reactor Power System being developed under Department of Defense/Department of Energy/NASA sponsorship.

agement, the program has been broken up into five major program elements or thrusts. The first major thrust is surveillance, acquisition, tracking and kill assessment (SATKA), which encompasses the five previously-mentioned system concepts: boost-phase infrared surveillance system, midcourse infrared surveillance, midcourse laser or radar imaging system, late midcourse to terminal airborne infrared tracking system, and a terminal imaging radar. In addition to the pursuit of technologies leading to major experiments conducted in support of each of these concepts, significant effort is underway also to gather radar and optical data on missiles and backgrounds and to investigate common technologies such as signal processing and the development of imaging algorithms. The Army and Air Force will each execute about 40 percent of the funds for surveillance, acquisition, tracking, and kill assessment in FY 86.

► The second major thrust is directed

energy weapons, with primary emphasis within the DoD upon space-based chemical lasers, ground-based excimer and free electron lasers, and space-based neutral particle beams. The Air Force is by far the largest executor of the directed energy work in FY 86.

The third major thrust is in the kinetic energy weapons area, which includes the concepts for space-based kinetic kill vehicles, space-based hypervelocity launchers, and ground-based endo- and exoatmospheric hit-to-kill interceptors previously discussed. All of the concepts are supported by major technology efforts in terminal homing, chemical and electromagnetic propulsion, fire control and acquisition and tracking. The Army will execute the largest portion of the kinetic energy weapons thrust in FY 86.

The fourth major thrust is systems analysis and battle management, where the main efforts are system and battle management architectures and the associated communications, command and

control technologies. This area has received much attention lately with the award of 10 one-million-dollar contracts for alternate architecture studies which will identify the key trade-offs of various total-system designs. The results of these studies will help General Abrahamson guide the individual technology programs toward the achievement of overall, integrated system objectives. The funds here are divided almost equally among the Army, the Air Force and the SDIC, with the services' primary thrust in technologies and the SDIC's in systems analysis.

The fifth major thrust includes an assortment of high priority technologies which individually do not take a sufficiently large fraction of the program's funding to warrant a separate program element for each. This includes major efforts in space system survivability technology, lethality and target hardening testing, space prime power from tens of kilowatts to megawatts, and space logistics with particular emphasis on launch, orbit transfer and on-orbit support. The Air Force is conducting most of the survivability, space power and space logistics work with the Defense Nuclear Agency directing the lethality and target hardening tests with assistance by the Air Force, Army, and DoE.

A considerable amount of growth in each of these five major thrust areas has been requested in the President's budget for Fiscal Year 1986. This growth is attributable to the fact that the many technologies which make up the Strategic Defense Initiative had each reached a point where they were ripe for exploitation. It is common for the funding of an emerging technology to grow rapidly as it is experimentally applied to potential weapon system concepts after an extended period of low-level research.

The goal for the Strategic Defense Initiative was eloquently established by President Reagan in March 1983, when he challenged all of us in the scientific community to create a means for rendering ballistic missiles impotent and obsolete.

The goal of the Strategic Defense Initiative has not changed at all since the President's March 1983 speech, even though the understanding of that goal by the program's opponents may have changed. The President's original goal still drives this research and technology program, with the need for the United States "to get started now", as he stated in his State of the Union address.

By JAMES J. HAGGERTY

1986: A BIG YEAR IN SPACE

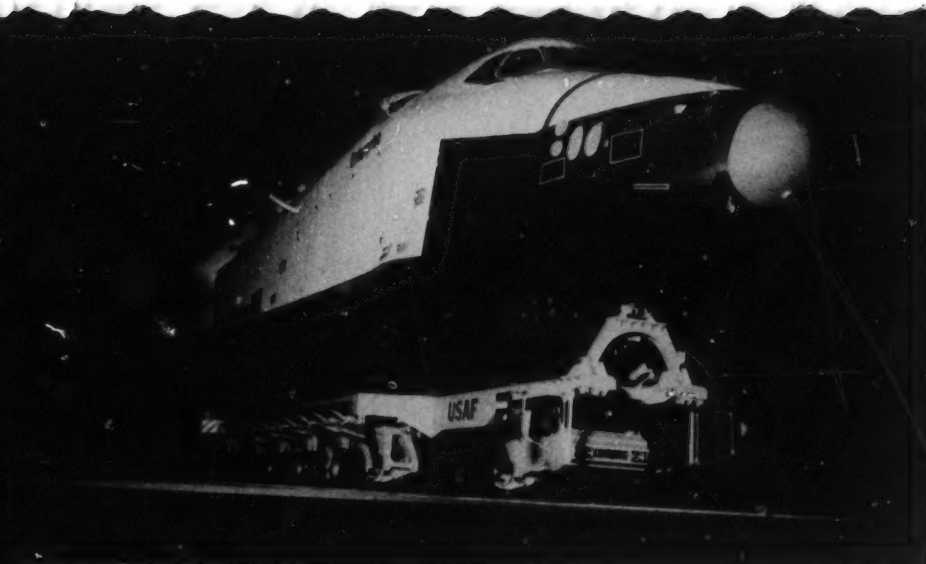
U.S. space accomplishments in 1984 marked the most eventful year of the Shuttle era, perhaps the most spectacular year since the first manned lunar landings in 1969. The year was highlighted by the debut of the backpack one-man spacecraft, Martin Marietta's Manned Maneuvering Unit (MMU); the subsequent use of the MMU in history's first recapture of an orbiting satellite; and the follow-up retrieval of two expensive communications satellites earlier stranded in improper orbits. The near-flawless performance of those difficult missions won the Collier Trophy for a NASA/industry/astronaut team as the year's most significant achievements in aeronautics/astronautics.

But wait 'til next year.

Over the 12-month span beginning in January, a number of major space programs in development for a decade or more will come to fruition if all goes as currently planned. Although there will be plenty of excitement, the year's happenings will not match the first steps on the moon for sheer drama; but in terms of scientific potential and capability advancement, 1984 may well surpass the Apollo year 1969. Among the projected highlights are:

- The start of Space Shuttle operations at Vandenberg Air Force Base, California and the first polar-orbiting Shuttle flight.
- A fly-by of the planet Uranus, never before explored by spacecraft and only dimly observed from Earth.
- An analytical look at Comet Halley from a new Shuttleborne observatory.
- Delivery to orbit of the most advanced space observatory ever built, potentially the most dramatic advance in astronomy since the invention of the telescope.
- Commencement of a multiyear mission that will eventually take an international spacecraft around the poles of the Sun.
- Launch of a highly sophisticated two-element spacecraft designed to make a comprehensive exploration of the planet Jupiter and perhaps—it's an en route option—the first close encounter with an asteroid.

These and other planned developments of 1986 are amplified in the illustrated summary that follows.



A



B

NEW SHUTTLE BASE

In March 1986, the Space Shuttle will make its first flight from the West Coast space launch complex at Vandenberg Air Force Base, California. The Orbiter *Discovery* will be directed into polar orbit, a first for the Shuttle; polar launches are impracticable from the existing launch base at Kennedy Space Center, Florida. Both Air Force and NASA Shuttle missions requiring polar orbit will be launched from Vandenberg, significantly increasing Shuttle capability.

Operated by the USAF Strategic Air Command's 1st Strategic Aerospace Division (1 STRAD), the Vandenberg facility is designed to support six to 10 Shuttle flights a year in the 1980s, eventually 20 a year.

In January of this year, 1 STRAD began a facility verification program that in-

volves "fit and function" checks of Shuttle hardware, payload operations and launch processing simulations to ensure readiness for the first flight. On February 1, the Vandenberg team completed the first "stacking" of a complete Shuttle—the Orbiter, the two solid rocket boosters and the external fuel tank—known as the Facility Verification Vehicle (FVV). The Orbiter used on the FVV is the prototype *Enterprise*, which is not equipped for space flight. Photo A shows the *Enterprise* being delivered to Vandenberg's Space Launch Complex Six by a 76-wheel transporter. At the Shuttle Assembly Building it is craned into place with the previously stacked booster and tank (Photo B). In Photo C, the complete stack is undergoing checkout on the pad.

C

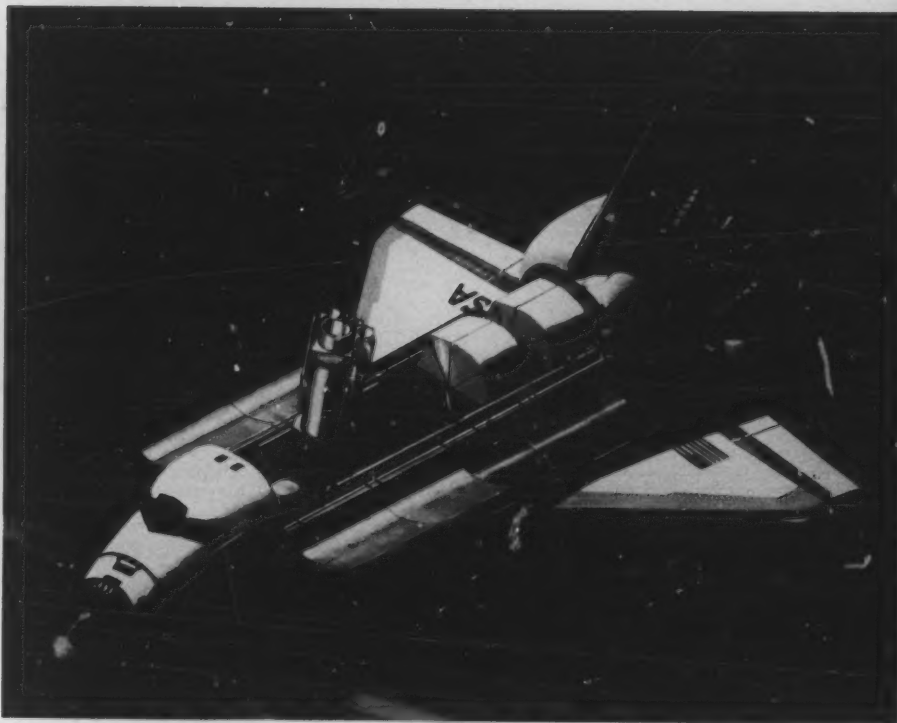


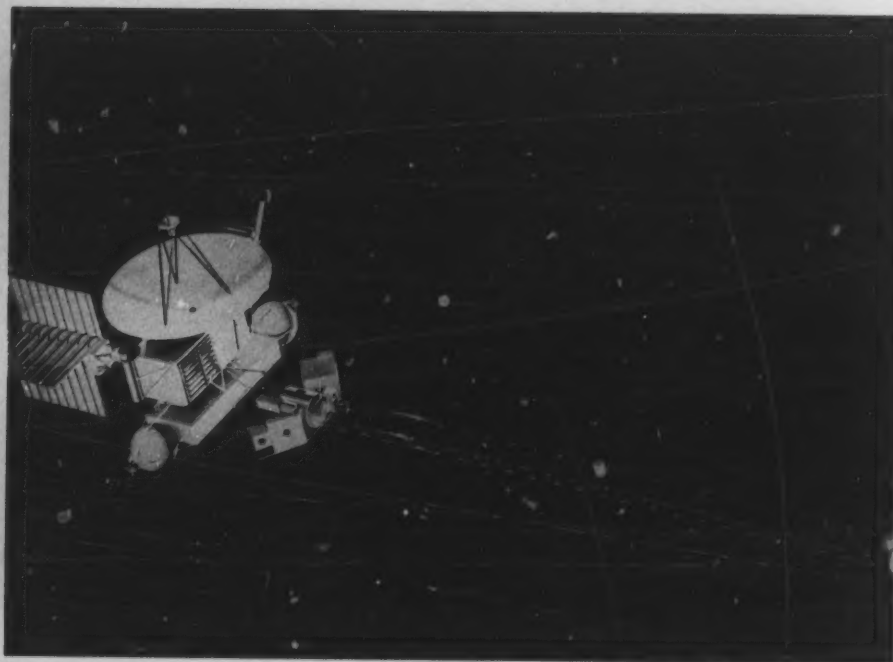
VOYAGER AT URANUS

Uranus, the seventh planet of the solar system, orbits the Sun at a distance of 1.8 billion miles, thus is only faintly visible to Earth telescopes. A close look at this little known planet is of prime scientific importance. Voyager 2, which departed Earth eight years ago and returned volumes of information about Jupiter and Saturn, will provide the first closeup views of Uranus next January, when it passes within 64,000 miles of the planet. If Voyager is still functioning after that encounter, it will continue toward Neptune, a billion miles farther, for a 1989 rendezvous.

SHUTTLEBORNE OBSERVATORY

March 1986 will see the debut of a new Shuttle-based observatory called *Astro*. Intended for service on a number of Shuttle missions, it is a system of three imaging telescopes designed to study celestial objects in ultraviolet light, which is largely invisible to ground telescopes because it is absorbed and filtered by Earth's atmosphere. The initial flight has been timed to coincide with Comet Halley's close approach to the Sun; *Astro*'s instruments will measure ultraviolet wavelengths and intensities as a means of determining the comet's composition and structure. For this seven-day mission, *Astro* will be fitted with cameras for photographing Halley in visible as well as ultraviolet light.





ULYSSES

In May 1986, the Space Shuttle will launch a pioneering spacecraft named Ulysses into a vast unexplored region of space known simply as "out of the ecliptic." The ecliptic is an imaginary extension of the Sun's equator. Earth and all the planets revolve about the Sun close to this plane, so the space above and below the imaginary equatorial plane has never been visited by spacecraft. Ulysses will be boosted into a trajectory that will take it on a five-year jaunt through interplanetary space and around the poles of the Sun. The mission is a joint effort of NASA and the European Space Agency (ESA). ESA is developing the spacecraft and half of the scientific payload; NASA is providing the other half and the spacecraft's power generating system.



GALILEO

To be Shuttle-launched in May 1986, Galileo is a two-element spacecraft intended to amplify earlier-acquired scientific information about the planet Jupiter. One element is an entry probe which, protected by a heat shield from temperatures expected to reach 14,000 degrees Fahrenheit, will descend into Jupiter's atmosphere and report first-hand data. In the accompanying artist's concept, the probe (the top-shaped object at left) is being released from the primary spacecraft. The main element will become an artificial Jovian moon, transmitting data and images of Jupiter and its satellites for 22 months. Hughes Aircraft Company and General Electric Company are building the probe, Jet Propulsion Laboratory the main spacecraft. Galileo may also make the first encounter with an asteroid; that's an option that NASA controllers can decide after launch. If the option is exercised, the encounter will take place in December 1986, one more event of the big year in space.



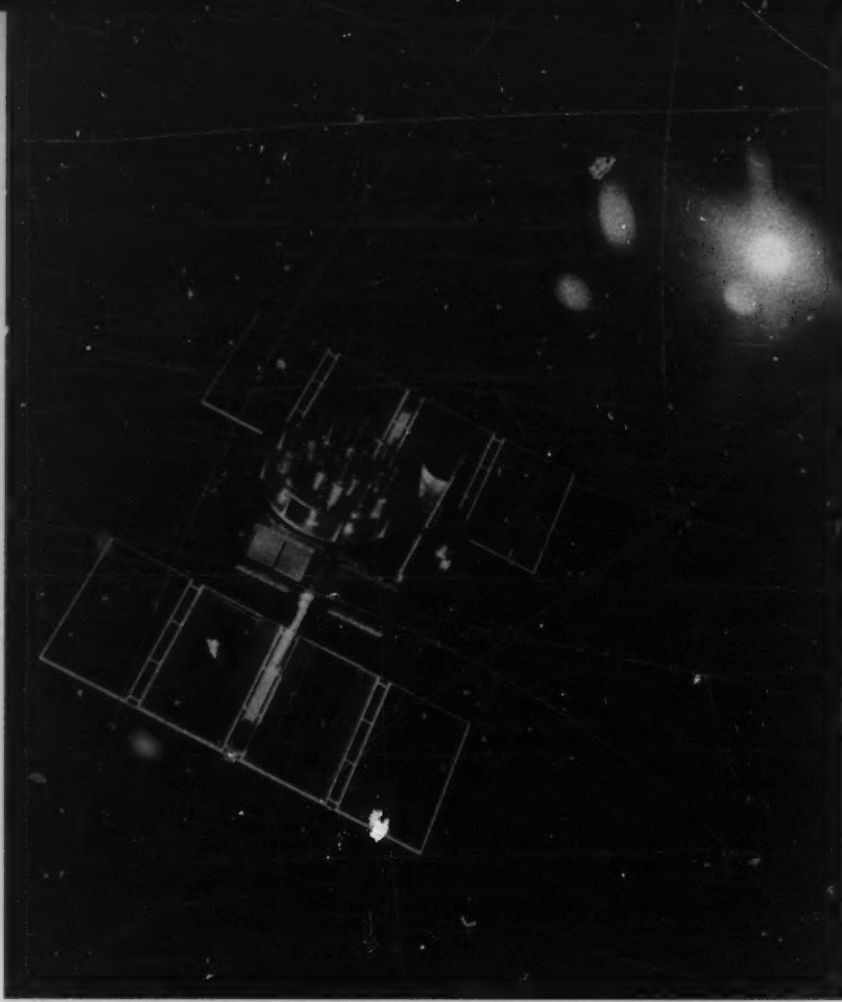
SPACE TELESCOPE

Potentially the greatest advance in astronomy since the 17th century invention of the telescope, the Hubble Space Telescope will be launched into low Earth orbit in August of 1986. The 43-foot long observatory, which will become the largest scientific payload ever sent into orbit, will operate at an altitude of 320 miles, free of atmospheric distortions that limit the vision of ground-based telescopes. Thus it will expand man's view of the cosmos about 350 times, literally allowing a look back in time some 14 billion years. The Optical Telescope Assembly was developed by Perkin-Elmer Corporation; Lockheed Missiles & Space Company is building the Support Systems Module and integrating the complete spacecraft.

UPPER STAGES

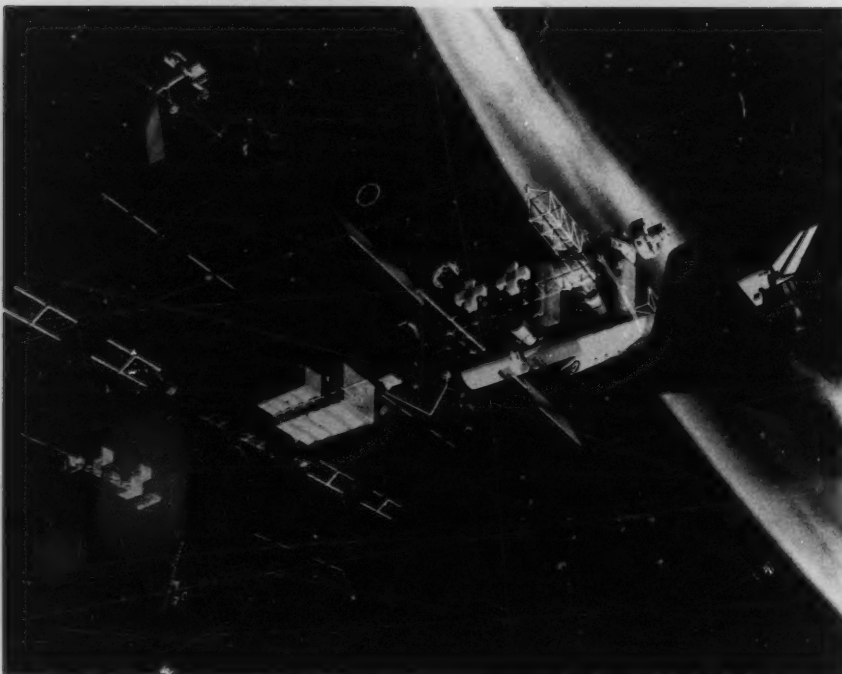
The most powerful upper stage booster designed for Shuttle use will make its initial flights on the Ulysses and Galileo missions. Known as Centaur G Prime (Photo A) it is one of two Centaur versions being developed by General Dynamics Corporation for NASA and Air Force programs. It is capable of boosting seven ton payloads into geosynchronous orbit or sending as much as 17½ tons into interplanetary trajectory. Another advanced upper stage—Orbital Science Corporation's Transfer Orbit Stage (TOS)—will become available for Shuttle use late in 1986; it is designed to boost medium-size payloads in the 6,000-13,000 pound range. TOS (Photo B) is being developed, in cooperation with NASA, as a commercial enterprise, with Martin Marietta Denver Aerospace as prime contractor to OSC. The TOS development team also includes United Technologies Chemical Systems Division and the Strategic Avionics Division of Honeywell Inc.





NAVSTAR

The Navstar Global Positioning System (GPS) is a network of navigation satellites and ground equipment designed to provide precise position fixing for weapons platforms. It represents an enormous advance in weapons delivery capability in that it provides space reference points for determining the location of a military craft/vehicle with a degree of accuracy never before attainable. The Air Force is testing the system with an interim network of six developmental satellites. In the fourth quarter of 1986, the USAF will launch the first advanced Block 2 satellites of the operational GPS, which will have 18 satellites in six different orbital planes; this will allow receiver-equipped Department of Defense units anywhere on Earth to fix their positions within 50 feet. The Navstars will be Shuttle-launched, three at a time, from Vandenberg Air Force Base. Full operational capability of the GPS, requiring all 18 satellites, is expected by the end of 1988.



SPACE STATION

By the end of 1986, contractor teams will have essentially completed the Phase B Space Station definition and preliminary design studies initiated in April of this year. That will pave the way for the big step: final design determination and the start of hardware fabrication in 1987/88. Some 80 contractors, organized into eight teams, are studying various aspects of the station on a competitive basis. NASA has not officially stated a date for initial occupancy of the station, but planning is directed toward launching the first—and possibly several—of the eight Shuttle missions required to assemble the station in 1993.

New Goals for Aeronautical R&D

Superefficient subsonic jetliners, 2,000-mile-per-hour passenger transports, and transatmospheric aircraft capable of cruising at the top of the atmosphere and flying into orbit—these are among the goals set forth by an Aeronautical Policy Review Committee established by Dr. G. A. Keyworth, II, Presidential science advisor and Director of the Office of Science and Technology Policy (OSTP).

Keyworth stressed that, in the face of strong and growing challenges from abroad, lasting U.S. aeronautical leadership will be maintained only by the vigorous application of a traditional American strength: innovative technology. There are, he added, aeronautical opportunities which, if actively pursued, could result in U.S. civil and military aircraft of clear-cut superiority, aircraft whose technical excellence could more than overcome foreign competitive approaches.

The task he assigned the Aeronautical Policy Review Committee was "to lay out a visionary roadmap that truly exploits (aeronautical) technological potential." Created in 1983, the committee responded with a report, released in April, that proposes three broad national goals to clarify and focus the direction of U.S. aeronautical R&D. The goals, in time-phased order of attainment, are:

- **Subsonics Goal**

Intended to build "trans-century renewal" of America's technological strength, the subsonics goal envisions advancing technologies applicable to a variety of subsonic aircraft. Most of these technologies could mature in the 1990s to lay a foundation for a new generation of highly efficient, affordable aircraft operating in a modernized National Airspace System. Types would include short, medium and long range transports and rotorcraft incorporating advanced drag reduction techniques, high speed turboprop engines, all-composite structures, high lift aerodynamic systems and flight control/guidance improvements.

Achievement of the subsonics goal would enable U.S. manufacturers to capture "immense civil aircraft opportunities by technologically superseding foreign competitive challenges." At the same time, the new technologies would support development of advanced military aircraft capabilities.

- **Supersonics Goal**

This goal involves development of pacing technologies for sustained supersonic cruise capability with long distance efficiency, which would permit linking the U.S. with the farthest reaches of the Pacific Rim in four to five hours. Keyworth emphasized that the Administration has made no commitment to a supersonic transport but "we are laying the groundwork, both in NASA and DoD, in the fundamental technologies essential for any future efforts in supersonic flight."

Such technologies include supersonic laminar flow control, major improvements in variable-cycle engine efficiency, noise abatement and lightweight, high-temperature structures. Successful integration of these technologies could make possible 600-passenger transports with speeds up to Mach 3.2 over a range of 5,500 miles with three times the fuel efficiency of current supersonic aircraft. Again, the new technologies would benefit military supersonic flight, through enhancements in basing flexibility, long distance responsiveness and survivability.

- **Transatmospherics Goal**

Research in this area would be directed toward developing a capability for routine cruise and maneuvers into and out of the atmosphere with takeoff and landing from conventional runways. Vehicles of this type depend on further technological progress in propulsion, materials and "intelligent" integrated flight controls. Research would draw upon progressive subsonic, supersonic and hypersonic advancements in aeronautics, as well as Space Shuttle experience. Applications of transatmospheric vehicles range from regular access to space to rapid point-to-point transportation.

The report states that such a research program will influence long range options for both aeronautics and space and will be significant to U.S. civil/military aircraft technology leadership in the 21st century.

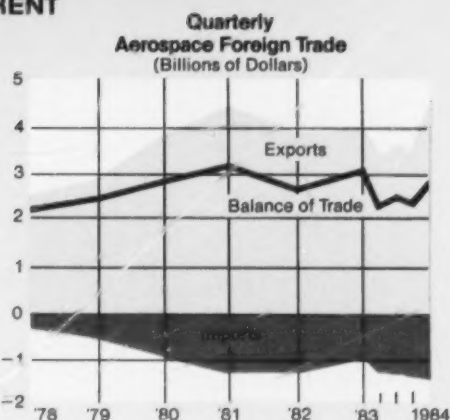
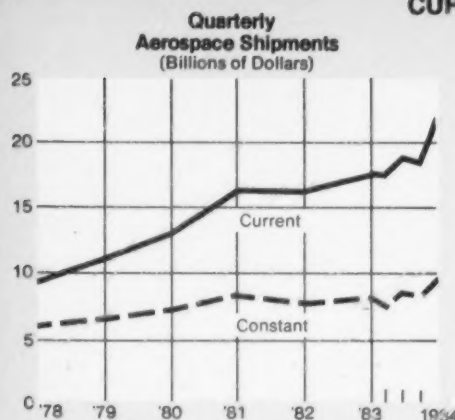
America's future in aeronautics, says the report, demands much more than a "business as usual" attitude. Citing barriers that impede technological advancement in both the public and private sectors, the committee suggested corrective actions that "should be pursued without delay," among them:

- Federal contracting procedures should be restructured to reflect a greater distinction between the procurement of research and technology and the procurement of hardware.
- Regulatory policy should encourage cooperative efforts for technology development among U.S. companies.
- Federal tax legislation should adequately stimulate private investment in timely technology development.

Chaired by retired Boeing vice president John E. Steiner, the Aeronautical Policy Review Committee included representatives of McDonnell Douglas Corporation, Garrett Turbine Engine Company, Rockwell International, Fairchild Industries, General Electric Company, Bell Helicopter Textron, Lockheed Corporation, The Boeing Company, the Air Transport Association and Massachusetts Institute of Technology. Government agencies represented included the Departments of Defense and Commerce, NASA, the Federal Aviation Administration and OSTP.

AEROSPACE ECONOMIC INDICATORS

CURRENT



OUTLOOK



ITEM	UNIT	PERIOD	AVERAGE 1966-1975	YEAR AGO	LAST QUARTER	LATEST QUARTER 4th QTR 1984
AEROSPACE MANUFACTURING						
Shipments	Billion \$	Quarterly	6.3	18.4	18.7	21.9
New Orders	Billion \$	Quarterly	6.5	26.1	19.3	27.4
Backlog of Unfilled Orders	Billion \$	End of Quarter	31.4	103.3	114.8	120.3
Inventories	Billion \$	End of Quarter	8.7	27.7	32.7	32.4
Capacity Utilization	Percent	Quarterly	77.5	70.4	76.5	76.5
DEPARTMENT OF DEFENSE						
Aircraft Procurement Obligations	Million \$	Quarterly	1,986	9,397	7,251	12,478
Missiles Procurement Obligations	Million \$	Quarterly	726	2,336	2,392	3,319
Aircraft Procurement Outlays	Million \$	Quarterly	1,741	5,815	5,901	6,298
Missiles Procurement Outlays	Million \$	Quarterly	664	1,821	1,529	2,292
NASA R&D AND SFCDC^a						
Obligations	Million \$	Quarterly	780	1,912	1,636	2,313
Expenditures	Million \$	Quarterly	789	1,626	1,341	1,680
FOREIGN TRADE						
Exports, Total	Million \$	Quarterly	1,037	3,695	3,604	4,203
Civil	Million \$	Quarterly	742	2,490	2,136	2,703
New Commercial Transports	Million \$	Quarterly	347	970	600	1,045
Imports, Total	Million \$	Quarterly	119	998	1,235	1,267
Civil	Million \$	Quarterly	NA	842	992	1,032
Balance of Trade, Total	Million \$	Quarterly	918	2,697	2,369	2,936
Civil	Million \$	Quarterly	NA	1,648	1,144	1,671
EMPLOYMENT: TOTAL						
Aircraft (SIC 372)	Thousands	End of Quarter	1,166	1,171	1,221	1,252
Missiles & Space (SIC 376)	Thousands	End of Quarter	650	585	611	626
FINANCE						
Profits (after tax) Based on Sales						
Aerospace	Percent	Quarterly	2.7	4.0	3.3	4.3
	Percent	Annually**	2.7	3.5	4.0	4.1
All Manufacturing	Percent	Quarterly	4.8	4.5	4.5	4.1
	Percent	Annually**	4.8	4.1	4.7	4.6
Plant & Equipment Expenditures	Billion \$	Calendar Year	1.03	2.91	NA	3.55
GNP DEFLATOR (1972=100)						
	Index	Quarterly	95.9	218.2	224.6	226.1
	Index	Annually**	95.9	215.3	221.4	223.4

*1966-1975 quarterly averages are computed as one-fourth of annual averages.

**Annual data are computed as the sum of the previous four quarters.

^a Effective 4th Qtr 1983, includes new budget category of "Space Flight, Control & Data Communications."

NA Not Available

Source: Aerospace Industries Association

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